# Foreword

*By: Dr. Joel Orr*

By the time I met Dave Weisberg, in the mid-seventies, he was already a computer-graphics veteran and a CAD pioneer. So his stories and remarks are those of an observer and participant, not a researcher from a subsequent generation. He was there as the discoveries and inventions that led to the computer-aided design we have today were being made, and he had an impact on them, as you will read herein.

The field of CAD has been blessed with numerous great innovators and a few good business people—but almost no chroniclers. It is something of a "cowboy culture," in which the heroes just keep on keepin' on until they're through; they don't retire and write their memoirs.

But happily for us, Dave decided to become a journalist, and to observe and write about the CAD industry professionally. This chronicle reflects that professional shift.

An engineer does not stop being an engineer just because of a shift in professional focus. It is with an engineer's eye that Dave's observations were made, and from an engineering point of view they were recorded and analyzed. This fact makes this book more than just an eyewitness account of events.

It took the viewpoint of a working engineer to note the effects of technology on the very practices of engineering. Not only are engineers now able to do what they did before much faster and more accurately—the way they approach design has changed as a result of the absorption and integration of new technologies.

Dave's book is at once a personal history, replete with vignettes that are the stuff of life; a history of the birth, infancy, adolescence, and maturity of a family of technologies; and a record of the sea changes that have happened in engineering as a result of those technologies. In short—a feast for CAD old-timers, engineering educators, and young engineers alike.

Enjoy!

Joel

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# Chapter 1

# Introduction

Engineering design probably started when an unknown caveman had an imaginative idea for making a better club with which to fend off a fellow caveman or bring home more meat for dinner. Ever since, people have attempted to create bigger and better structures and products to improve their lives. I have always been amazed at how the Egyptians built the Pyramids and the Romans the Coliseum and Forum with the tools they had at hand. Even in the past century, it is amazing to those of us whose lives are centered around computers to envision building structures such as the Golden Gate Bridge and the Empire State Building or designing hybrid automobiles and supersonic aircraft without the tools we have become accustomed to.

The computer has changed the practice of engineering forever. In the most simplest terms it has taken the drudgery out of the design process. In the words of James Clerk Maxwell "the human mind is seldom satisfied, and is certainly never exercising its highest functions, when it is doing the work of a calculating machine."[1]

Today, the Computer-Aided Design (CAD) industry is a multi-billion dollar business with literally millions of engineers, architects, and drafters using these computer systems on a daily basis. The technology has clearly changed how many professions are practiced, predominately, but not in all cases, for the better. It was not always obvious that we would succeed in this endeavor. Computers were too slow, the software plagued with errors and functional shortcomings and management didn't want to rock the boat. Eventually, the industry solved both the technical and management issues and today few would want to tackle any complex design project without the latest available technology.

This book is intended to tell the story about how we have gone from a few academics with great foresight to an industry that produces the tools used to design everything from new razors to airplanes that fly around the world non-stop. As in few other disciplines, the work of developing this technology was built on the experiences of those that went before. It makes for a fascinating story.

### How Did I End Up Writing This Book?

I first decided that I wanted to be an engineer when I was twelve years old and was watching the construction of a school building a few blocks from my home. Unlike many of my friends, I never wavered from this goal while in junior high school and high school and at the age of 18 found myself a freshman at the Massachusetts Institute of Technology firmly intending to become a civil engineer and build bigger and better dams and bridges. That started to change when at the end of a sophomore surveying final exam in the spring of 1957, Professor Charles Miller (see Chapter 5) asked me if I wanted to work for him that fall on a project he was supervising that involved applying computer technology to engineering design.

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[1] Goldstine, Herman - *The Computer - from Pascal to von Neumann* 1972 - Princeton University Press, p. 343

Talk about a life changing decision. For the next half century I was involved in the development, marketing and writing about computer technology as applied to engineering design and manufacturing. Miller frequently talked to us about the analogy between how machines changed physical labor and how computers would change the way people solved intellectual problems.

This book is my attempt to document how the computer changed the practice of engineering. I have chosen to do it by looking at the companies and individuals who created this new technology, primarily through the eyes of someone who was there.

As with anyone writing this type of book, it is probably best to lay out my credentials up front. Academically, I have BS and MS degrees in civil engineering from MIT. The MS may be a little misleading in that Professor Miller was attempting to change how civil engineering was being taught at MIT and was experimenting with reaching out to other disciplines. I ended up doing as much graduate work in business management and operations research as I did in civil engineering. There were few computer science courses at the time – in fact we didn't even call it computer science.

By the time I received my masters degree there was little question in my mind that I wanted to work in the new emerging computer industry rather than practice civil engineering. This is when I met the second person who had a major impact on my professional career, Jack Gilmore (that is his picture on the cover of this book). Jack was the vice president of a small software consulting firm that was engaged in developing a graphics system for doing computer-aided drafting (see Chapter 6). Except for several years in the Army, I worked for Jack at Adams Associates (later named Keydata) until late-1969. Nearly all my work involved computer graphics including the design and implementation of the first graphics-oriented oil refinery control system.

This was followed by a stint in corporate planning at URS, a major architectural and engineering firm, and then working as a salesman for Calma, one of the first commercial CAD[2] vendors (see Chapter 11). After Calma, I worked for Tektronix in several different marketing and sales management positions. Tektronix was the major vendor of graphics terminals in the 1970s and early 1980s. For several years it attempted to develop an end user CAD system business for which I ran the field operations side.

In 1980 I joined Auto-trol Technology (see Chapter 9) where I spent the next 12 years in a variety of marketing, sales and software development management positions. For several years in the early 1980s I was responsible for the company's competitive analysis activity. Being a natural pack-rat (just ask my wife), I saved a considerable amount of material from that work that has helped in writing this book.

My career took a significant change in direction in late 1991 when I formed Technology Automation Services and began publishing *Engineering Automation Report*. For the next eight years I covered the CAD industry, interviewing many of the people mentioned in succeeding chapters. In 1994, I acquired the *Anderson Report on Computer Graphics* started by Ken Anderson in 1978 and then in 1997 I acquired the *A-E-C Automation Newsletter* started by Ed Forrest in 1977.

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[2] For simplicity, I have decided to refer to this industry as Computer-Aided Design or CAD rather than use all the other acronyms that are applicable to specific aspects of the technology such as CAE for Computer-Aided Engineering, EDA for Electronic Design Automation, CAM for Computer-Aided Manufacturing or PLM for product Lifecycle Management. I have included an appendix explaining much of the nomenclature applicable to the material in this book.

 

In 2000 I sold the newsletter business to Cyon Research which subsequently acquired Stephen Wolfe's *Computer-Aided Design Report.* A decade earlier Wolfe had acquired *CAD/CIM Alert*, one of the industries other early newsletters. One result was that I ended up with nearly complete runs of the five most significant newsletters that covered the CAD industry. These provided a significant portion of the background material for the book.

**Documenting an Evolving Industry**

Why write a book about the CAD industry? That is a reasonable question and one I have attempted to answer many times while working on this book. This is an industry that got its start barely 60 years ago, shortly after the Second World War. Although we are starting to loose some of the early pioneers, many of the people who were instrumental in much of the early research and involved in forming the companies I write about are still alive and kicking. That might not be the case 20 years from now. Therefore, I felt that it was important to document this important industry while they were still in a position to contribute.

Over the course of my career in this industry, I have been fortunate to meet and get to know many of the individuals I write about. With few exceptions, they have all been very helpful in answering my many questions and in volunteering material I might not have otherwise have had access to.

The other reason for doing it is that no one has written a book about the industry as a whole and only a few books have been written about individual companies in the CAD industry. In fact I can only think of two – John Walker's *The Autodesk File* and Richard MacNeal's *The MacNeal Schwendler Company – The First Twenty Years*. There have been a number of books that cover specific aspect of design technology such as Donald LaCourse' *Handbook of Solid Modeling*, David Rogers' *An Introduction to NURBS* and Jami Shah and Martti Mäntylä's *Parametric and Feature-Based CAD/CAM*. On the other hand, there have been countless books written about using one or another of the various CAD software packages being sold. For example, David Cohn alone has written or co-authored over 15 books on AutoCAD.

This is a fairly close knit community. One of the aspects that make it an interesting story is the way key people have moved from one company to another over the course of the past 40 years. A number of people have been involved in two, three or even more start-ups, each time trying to create the next great technology.

One of the other reasons I wanted to write this book is that there is a lot of inaccurate information floating around. One well-respected consultant has on his web site that Computervision and Applicon were founded in 1972 when the were actually started in 1969. Another market research firm had Auto-trol Technology's revenue in 1980 as 87% mechanical when in fact, mechanical was a much smaller portion of the company's business. I have gone to great pain in an attempt to ensure that the facts contained in this book are as accurate as possible. Where a statement is my opinion I have tried to make it clear that such is the case.

**What This Book Is and Is Not**

As any reader can see, this is a fairly lengthy book. It could easily have been several times as large - perhaps two or three volumes. My intent was not to outdo Will and Ariel Durant and their 11 volume *History of Civilization*. The hard decision was where to draw the line. One part of the decision was to write about what I was most familiar with, both from a research perspective and the companies described in detail.

A significant result is that the book covers early research at MIT but not a lot about what went on at other universities. Unfortunately, this means just passing attention has been paid to work done at Cornell, Syracuse, the University of Utah, the University of Rochester and Rensselaer Polytechnic Institute. Also, significant work done at the University of Cambridge in England is covered only as it affected other elements of this story.

The second decision was to focus on companies and technologies applicable to mechanical design and manufacturing with some AEC (Architecture, Engineering and Construction) involvement. Even in the latter case, I do not spend much time on architecture per se. It could easily be a book in its own right as could Electronic Design Automation (EDA) which also is covered only to the extent that the companies I do write about were involved in that technology.

For the most part, the book covers software and systems companies headquartered in the United States. The fact remains that with just several significant exceptions, the vast majority of the worldwide CAD industry has been centered in this country. The major exception is Dassault Systèmes of France and that company is covered in depth in Chapter 13. Another exception is the field of architectural modeling which has been driven in part by several European firms, but that is a subject for another day.

Over the years there have been hundreds if not thousands of companies that have developed hardware and software products used to automate the engineering design process. The decision of which to cover has strictly been mine and I apologize to those, including some moderately successful firms, that space simply did not allow me to cover.

As the reader will see, I do not delve too deeply into the technology used to support CAD. There are no formulas describing how to solve the intersection of curved surfaces or discussion of the intricacies of object oriented software. I do make the assumption that the reader is generally knowledgeable about computer hardware and software although perhaps not as to how it applies to the CAD industry. There is an appendix that helps explain some of the terms and acronyms that are used.

Each chapter on a specific company stands on its own although I have tried to minimize redundancies between chapters.

**Help From Many Sources**

I would be hard pressed to thank everyone who has provided information for *The Engineering Design Revolution*. My standard statement in recent years has been “ don’t throw it out, just ship it to me.” In no particular order I would like to thank Steve Wolfe, Brad Holtz, David Cohn, Joel Orr, Dick Sowar, Pat Hanratty, Dick Harrison, Fontaine Richardson, Carl Howk, Phil Villers, Tom Lazear, Rachael Taggart, Lee Whitney, Rick Carrelli, Steven Weisberg, Greg Smith, John Baker, Peter Marks, Dave Albert, Dick Miller, Russ Henke, Charles Lang, and everyone else who provided information and took the time to discuss their experiences.

 

# Chapter 2

# A Brief Overview of the History of CAD

**Author's Note:** The purpose of this chapter is to provide an overview of how the Computer-Aided Design (CAD) industry evolved without repeating any more than necessary the material that appears in subsequent chapters.

## Introduction

I have always been fascinated by old structures and machinery. Buildings such as the Coliseum in Rome are all the more amazing when one realizes that two thousand years ago builders had none of the construction equipment we take for granted today nor did they have any of the tools for creating designs that we now use. It was more of an art form than traditional engineering with the master builder directing the work of thousands.

Today, the Coliseum exhibits only part of its past glory. On the other hand, many of the magnificent cathedrals and castles built in Europe during the Middle Ages still stand and many have been in continuous use every since they were first constructed.[1] While we have many examples of early construction, few machines from that era still exist. Most were war machines built to assault the enemy's castles and were probably destroyed in the process.

For centuries, engineering was focused on war, either building defensive fortifications or the machines to attack these fortifications. In fact the first non-military engineering discipline is called "civil" engineering to distinguish it from its military counterpart. Here also, few documents exist today describing how these early military war machines were built. Those that do exist were done on parchment or scratched into clay tablets.

That is not to say that these early builders did not use sketches and drawings. As an example, the Greek Parthenon could not have been constructed unless someone carefully calculated the size and shape of each stone that went into the building. Most likely, some method was used to document that information since many people were involved in the work. It was only during the early part of the 15th century that the concept of graphic projections was well understood by early Italian architects. This was about the same time that paper began to replace parchment as a drawing medium.

Existing engineering drawings describing machines and buildings date back to the fourteenth and fifteenth centuries. Most of these are in bound volumes stored in European museums and libraries, particularly in southern Europe, and viewing them is restricted primarily to academic researchers. Today, we would describe them more as sketches than as technical drawings. They were not to scale nor did they have dimensions. Many of these documents contain extensive textual descriptions that help one understand the intent of the drawings.

Early engineering drawings served two purposes. On one hand, they were a reference experienced craftsmen used to build or construct what was portrayed. While the drawings were more symbolic than what we are familiar with today, these craftsmen

[1] Wilkinson, Philip, *Amazing Buildings*, Dorling Kindersley, New York, 1993

 

understood the intent of their iconic descriptions and were not concerned by the lack of dimensions since every machine or building they worked on was unique. The other function of these drawings, particularly those collected in portfolios, was for presentation to the designer's patron, either a prince or wealthy merchant.[2]

Some of the best known early engineering drawings is the work of Leonardo da Vinci. While he is well known for his Mona Lisa, he was also a designer of military machines and forerunners of today's industrial machines. Leonardo's design work was artistic in nature - more illustration than engineering drawings. No multi-view drawings of any of his designs are known to exist today. Yet during the past century, skilled craftsmen were able to construct models of many of his designs working strictly from his sketches.

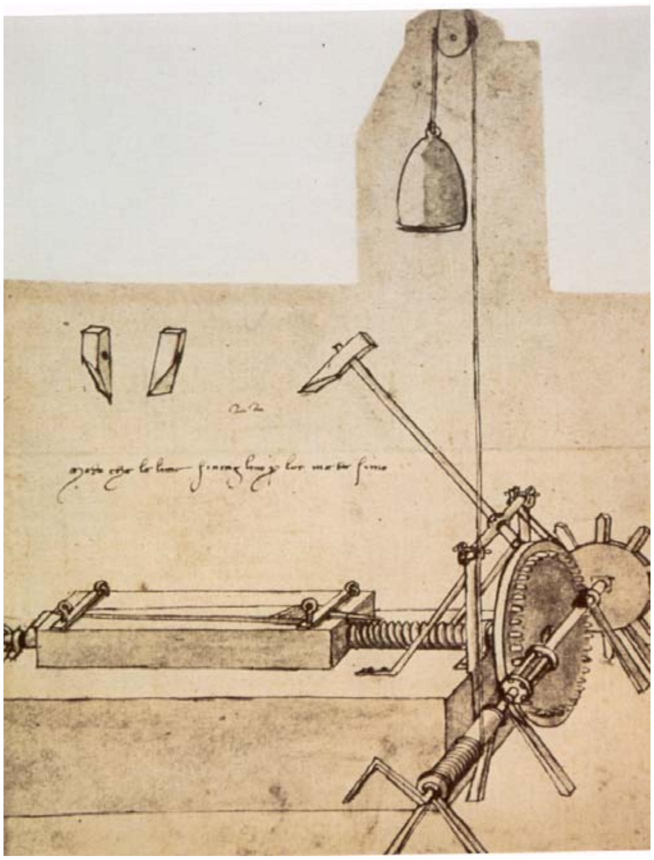

Figure 2.1
Leonardo da Vinci Machine for Cutting Files

> "Both the drawing's beauty and the ingeniousness of the mechanics make this file cutting machine very interesting. The operation is completely automatic: the weight falls unwinding the rope and activating both the rise and fall of the hammer and the progress of the piece to be cut, by using gears and levers. The complete automation not only helps Man but also gives more homogeneous results, foreshadowing modern production processes."[3]

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[2] Lefèvre, Wolfgang, *Picturing Machines 1400-1700*, MIT Press, 2004
[3] Cianchi, Marco, *Leonardo's Machines*, Edizioni Becocci – Largo Liverani, Florence, Italy

**Early Drafting Practice**

Most early practitioners of engineering drawings – such as Leonardo were also artists. Gradually, a realization developed that drawings had to stand on their own merits and that greater precision was needed. One early proponent of this belief was Leon Battista Alberti who, in 1435 and 1436, wrote two works that explored the need to incorporate more Euclidian geometry in contemporary drawings.[4] He also proposed drawings with multiple views rather than the single view then common.

Modern engineering design and drafting practice can probably be traced back to the development of descriptive geometry, especially the work of René Descartes (1596–1650) and Gaspard Monge (1746–1818). Engineering drawing began to evolve more rapidly in the late 18th century and picked up speed with the Industrial Revolution of the 19th century.

Peter Booker, in *A History of Engineering Drawing*, does a good job distinguishing the more technical practices of the European continent from the craft practices of England. He also describes in depth how early drafters (many of whom actually had degrees in engineering) used water color paints to highlight their drawings. This practice lasted until the early part of the 20th century. What is somewhat surprising is the fact that drafting standards, as we know them today, were not taken seriously until after World War I. The first American standard in this area was not approved until 1935, just two years before I was born.[5]

It is my impression that a major catalyst in the development of technical drawing was the growth of the patent process. In order to receive a patent for a new device, one had to submit drawings in specific formats. This was complicated by the fact that until the development of blueprints, no means existed to economically copy drawings and if multiple versions or copies of a drawing were needed they had to be copied or traced by hand. Sir John Herschel discovered the blueprinting process in 1840 and introduced it in the United States in 1876 but it was much later before it was widely used.

Early engineering drawings were often works of art. Like contemporary penmanship, this is a skill that few retain. Permanent drawings were often made with ink. An initial drawing was done using a pencil, T-square, triangles, scales, irregular (French) curves and drawing instruments such as compasses and dividers. Early drafting text books spent pages describing how to sharpen pencils and how to hold them to obtain an even line.

Once the pencil drawing was done, a sheet of tracing cloth would be tacked or taped over the original drawing. Each line would then be copied using pen and ink. Particular attention was always paid to lettering on the drawing. Over the years, various templates and other devices were introduced that enabled drafters to produce consistent quality lettering. Perhaps the most commonly used device was the Leroy Lettering Set manufactured by Keuffel & Esser. The set consisted of several templates of various sizes and a pen device that followed the shape of the

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[4] Lefèvre, Wolfgang, *Picturing Machines 1400-1700*, MIT Press, 2004, pg. 176

[5] Booker, Peter Jeffrey – *A History of Engineering Drawing* – Chatto & Windus 1963

 

letter in the template and reproduced that character in ink on the drawing. The company sold a variety of templates with different fonts.

Another major advance was a device called a Universal Drafting Machine as shown in Figure 2.2. This device basically combined the T-square, triangles, scales and protractor. It enabled the drafter to create perpendicular lines at any orientation. Among the manufacturers were Universal Drafting Machine Company, Frederick Post, Bruning, and Keuffel & Esser. The latter two are of particular interest in that they subsequently attempted to develop CAD system businesses selling mid-priced systems. Both lettering templates and drafting machines are still sold today although it may be hard to find a local dealer.

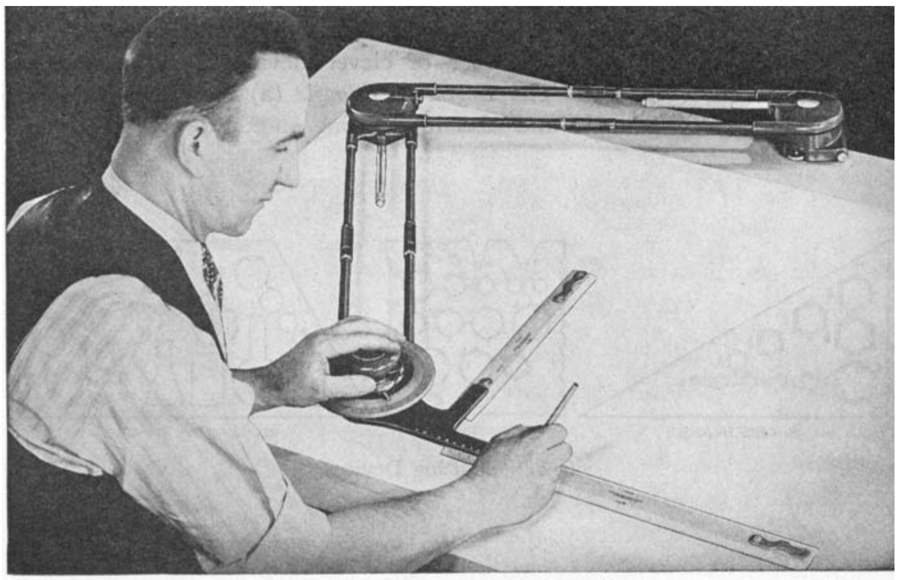

Figure 2.2
Universal Drafting Machine

Eventually, different engineering disciplines developed their own methods and approaches to engineering design and drafting. Architects had a style that was applicable to their work but was much different than what aeronautical engineers used. A major problem in the latter case was the need to produce accurate drawings at 1:1 scale for large components of an airplane since it was not possible to convert smaller drawings into the templates needed to produce these parts. Figure 2.3 shows several engineers and technicians creating a aircraft master layout.

During the decades following the Second World War, drafting equipment suppliers introduced a variety of materials to improve the productivity of the drafting process. Instead of drawing every detail on a drawing, stickers representing these items could be applied to the drawing. Together with a new generation of reproduction machines, the time to create routine drawings was reduced substantially.

 

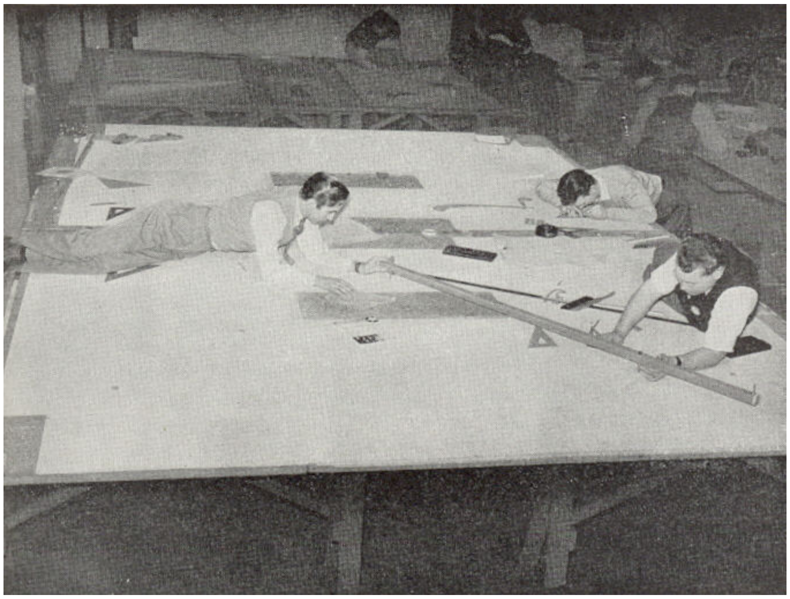

Figure 2.3
Creating an Aircraft Master Layout

In addition to the difficulty of producing engineering drawings, the design process itself was complicated, particularly by the lack of computational machines. I clearly remember one homework assignment in structural engineering in the late 1950s. The problem was a fairly straightforward two-story building - perhaps three by four bays. Working with simply a pad of paper and a slide rule, the assignment took most of a weekend. I didn't learn much about structural design but it did sharpen my arithmetic skills. Today, a student with a notebook computer can work on a building ten times as large and learn much more about what makes for a good design by trying different size structural members and different arrangements of these components.

Calculations were typically done with slide rules, electromechanical desk calculators and handbooks of mathematical tables and engineering data. Many technical calculations were done using logarithms which enabled multiplication and division calculations to be done using addition and subtraction. The most popular handbook for doing these calculations was first published in 1933 by Dr. Richard Burington. Unfortunately, these handbooks often contained minor errors. Burington's handbook was reprinted numerous times, each with corrections from prior editions.[6]

The engineering design process, including the preparation of drawings, was fraught with opportunities for error. One result was that every calculation and drawing was checked multiple times, especially when the consequences of an error could be disastrous. While computers have taken much of the drudgery out of engineering design, we know they are not perfect and it is still possible to make horrendous mistakes if one does not exercise the appropriate levels of care.

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[6] Burington, Richard S., *Handbook of Mathematical Tables and Formulas,* Handbook Publishers, Sandusky, Ohio, 1955

 

### Understanding the technology food chain

There is a phenomenon that takes place in the computer industry that is the reverse of the biological food chain. Except in this case, rather than the larger animals eating successively smaller animals the lower levels of the technology food chain absorb the capabilities of the higher levels. This phenomenon explains both the vast improvements we see in performance coupled with steadily reduced costs, particularly in regards to hardware.

So how does all this relate to design automation technology? One can look at the components of a computer system as being similar to a food chain. A system used for CAD applications might be organized somewhat as shown here:

Training and system usage
Customized applications
Information services
Standard applications
Application development tools
Database technology
Modeling and drawing production
Graphics systems
Operating systems
Computer systems
Specialized expansion boards
Function specific circuits
Computer microprocessor(s)

What is taking place in the computer industry is that specific capabilities are relentlessly moving down the food chain. Functions that once had to be done as part of an application package are now done in the operating system, and functions that once were done in the operating system are now part of the basic computer processor. Typically this results in faster performance as these functions move closer to the core of the computer. It also has the benefit of reducing costs.

One easy example to follow is what happened over time to floating point processors. Thirty to 35 years ago most minicomputer systems handled floating point operations with software routines embedded in the operating system. The need for greater performance encouraged the computer manufacturers to fabricate hardware floating point accelerators. These were typically the size of a small refrigerator and cost $20,000 or more. Early engineering workstations typically came with board-size floating point options that sold for several thousand dollars. During the mid-1980s, a number of semiconductor manufacturers developed individual chips or a small set of chips that performed the same floating point operations as did the add-in boards. These chips were simply added to the computer's motherboard. In the PC world, they were called math coprocessors. The manufacturing cost came down dramatically, the computer systems vendors easily incorporated these chips into their products and performance improved. The next step involved adding floating point functions to the basic microprocessor chip.

Performance improved since data did not have to flow between multiple circuit boards or even between individual circuits. Floating point operations are virtually transparent to today's computer systems and operating systems. In fact, most non-technical users are not even aware that this capability exists it has become so ubiquitous.

There are many other places in the technology food chain where functions have moved from one level to a lower level. Graphic services software is a good example. Graphic services are those functions that handle user interactions in a graphic system and display requested images on the display screen. In the past, every CAD system vendor invested a significant portion of its development resources producing software to handle these functions. There were two reasons for doing this. First, standard software was not readily available from the hardware vendors and second, this was how software vendors attempted to discriminate their products from competitive products.

Over time, industry standards such as X-Windows, MOTIF, and Open GL became accepted in the market and workstation and PC vendors began offering this software as part of their standard operating system. As a result, the vendors of application software revised their development strategies. They began to use standard operating system functions instead of proprietary software code for these tasks. Typically, 80 percent or more of the earlier proprietary software was replaced through the use of standard techniques incorporated in the operating system.

There are many other examples that could be used to explain this concept including graphic cards, networking, file management software and printer support. In the early days of the CAD industry, system vendors had to spend considerable effort designing basic hardware components and programming foundation-level software functions. Today's PC comes with all these capabilities built in and as a consequence CAD software vendors are able to concentrate their development resources on providing enhanced and more reliable applications.

For many year, programmers spent considerable effort compensation for limited main memory, small data storage devices and slow performance. The changes since the first commercial system were introduced have been astounding. In 1972 vendors such as Calma agonized over the cost of increasing their systems main memory from 16KB to 24KB. Disk drives were typically 5 to 20MB. And this had to be shared by typically four users. Today, you can buy a PC with 2GB of memory and a 250 GB disk drive for about $1,000. Companies that were successful were the ones that understood the pace the technology was changing and focused their R&D on what would be rather than what had been.

As we will see in following chapters, many companies never did understand these concept or were simply incapable of adapting to the fast pace the underlying technology was changing.

**The computer begins to change engineering practice.**

Chapters 3 and 4 provide a detailed description of some of the early developments involving computer graphics and research in applying computers to design and manufacturing. It is not my intent to duplicate that information here. Rather, lets just try to put this pioneering work in perspective.

Early computer development in the mid-1940s was mostly funded by military agencies and these machines were used to calculate information such as ballistic trajectory tables. In fact the term "computer" was originally used to describe the people who did these calculations manually. A decade later, IBM, Sperry-Rand and a few other companies began delivering computers to large engineering organizations, especially in the defense and automotive industries. Gradually, a number of programs for solving engineering problems were developed. In some disciplines, such as highway design, programs were readily shared between users while in other areas they were treated as highly proprietary.

The typical process for solving a technical problem involved the engineer filling out a coding form with applicable data. These forms would then be given to a keypunch operator who would produce a deck of punch cards and perhaps a listing of the data. The engineer would then review the numerical listing for errors and have the keypunch operator make corrections if necessary. The card deck would then be submitted to a computer operations scheduler who would submit the job to be executed.

These computers ran one job after another in what was referred to as a batch operation. The results of the computer run would then be provided to the engineer in the form of a numerical listing. Frequently, this meant that someone had to carefully plot the results in a way that enabled them to be visually interpreted. The overall process was referred to as a "closed shop" and it could take anywhere from a day for a minor problem to several weeks for a complex problem.

Lower cost computers that could be operated directly by engineering departments began to appear in the mid 1950s. Machines such as the Librascope LGP-30 (Librascope General Purpose) were vacuum tube machines that were slower than today's hand-held calculators but still provided a substantial advance over manual calculations. Output was mostly in the form of numerical listings although digital plotters from CalComp Computer Products began appearing around 1960.

IBM introduced the very popular 1620, an all-solid-state computer, in 1960. This machine leased for about $3,000 per month (most IBM computer were leased rather than sold outright at the time) and had performance of less than 0.01 MIPS (Millions of Instructions Per Second). While this is incredibly slow by today's standards, it was more than adequate for solving many engineering problems.

Large mainframes such as the IBM System 360 Model 60 leased for $40,000 per month and had performance of about 0.36 MIPS. These computers supported double precision floating point arithmetic and therefore were used for more complex engineering analysis applications.

**Development of in-house CAD systems**

In the mid-1960 time frame there were no commercial graphics systems on the market except for the Control Data Digigraphics system described in Chapter 6 and only a few of these were sold. The need for computer-based graphic systems to improve the productivity of engineers and drafters was slowly being recognized by large manufacturing companies, especially those in the automotive and defense and aerospace industries. Some of the work undertaken by these companies is described in Chapters 3 and 4.

This early work fell into two categories. On one hand, automotive companies such as Renault and Ford focused on the mathematical definition of complex surfaces while other companies, such as Lockheed California focused on improving drafting productivity. The Renault work eventually evolved into Dassault Systèmes's CATIA while Ford's PDGS software is probably still used on occasion today. Lockheed's work, of course, resulted in the CADAM product described in Chapter 13.

What was common to this in-house activity was that these companies used large mainframe computers, primarily those produced by IBM, and they mostly used vector refresh graphics terminals. A key hardware development was the introduction of the IBM System 360 product line in April 1964 which included the Model 2250 refresh graphics terminal. In subsequent years a number of companies including Adage and Spectragraphics produced terminals that were "plug compatible" with IBM's equipment, but typically less expensive. Other than CADAM and CATIA, little of this in-house work led directly to successful commercial systems.

**Introduction of commercial systems**

The CAD industry, as it subsequently evolved, started in 1969 with the formation of Applicon and Computervision. They were joined within a few years by Auto-trol Technology, Calma and M&S Computing (Intergraph). These companies and other early industry pioneers are described in later chapters.

While the in-house systems mentioned above used mostly mainframe computers and vector refresh graphics terminals, the early commercial systems used minicomputers such as the Digital Equipment PDP-11 and the Data General Nova-1200 and Tektronix storage tube displays. The typical system consisted of a 16-bit minicomputer with an 8KB or 16KB main memory, a 10MB or 20MB disk drive and one to four terminals. Most systems included large digitizer tables, keyboards for command entry, a tablet for coordinate entry and a digital plotter. The primary manufacturers of plotters at the time were CalComp, Gerber and Xynetics.

The typical system included a considerable amount of proprietary hardware. For the most part, these companies were equipment manufacturers who developed software to help sell their hardware. Fifteen years later most were struggling to make the transition to a software business model where industry-standard computer hardware was being used. Early systems were predominately two-dimensional drafting oriented with a particular focus on integrated circuit and printed circuit board layout. In the latter case, artwork was often generated on photoplotters produced by Gerber Systems.

A typical single station system sold for about $150,000 in 1972 with additional stations costing perhaps $50,000 each. This is equivalent to about $700,000 and $230,000 respectively 25 years later. Domestically, all these companies sold their systems through a direct sales organization. With just a few exceptions, the sales people were all men. Internationally, country distributors were utilized.

These systems were marketed predominately on the basis that they could reduce current operating costs. If you had a drafting department with 20 drafters, buy one of these systems, run it around the clock and you could get the same amount of work done with perhaps 10 or 12 people. In some cases, productivity improvements were truly spectacular, especially within organizations that did a lot of repetitive work. Most of these early systems had user-centric programming languages that facilitated the development of automated processes for generating standardized drawing working off minimal input data.

Performance was often an issue and early manufacturers put significant effort into building graphic interfaces that would speed up the process of generating display images. When a graphical element was moved or deleted from a storage tube display, the entire image had to be regenerated. Adequate performance required imaginative software and specialized hardware.

Throughout the 1970s, the CAD industry grew from virtually zero to a billion dollar hardware and software business. New companies constantly joined the fray but the market was dominated by the five turnkey vendors mention earlier.

**Evolution of geometrics modeling**

One area where university research played a significant role in the evolution of the CAD industry was in geometric modeling, both in regards to surface geometry and solids modeling. The earliest CAD systems simply handled two-dimensional data, emulating traditional drafting practices. The initial transition to three dimensions was done using wireframe geometry – points in space and the lines connecting these points.

Solid objects and surfaces were defined simply by lines that represented the edges of the geometry. Without additional information, it was not possible to generate shaded images of wireframe objects nor could hidden lines be removed without manual intervention. Obviously, better methods were needed.

Surface modeling technology was driven by the automotive and aircraft industries since manually defining and manufacturing sheet metal parts for these vehicles was becoming increasingly time-consuming and costly. One just needs to compare the boxy Ford Model A of 1930 to the 1975 Chevrolet Nova to see how the automotive industry was changing. Likewise, new jet aircraft required smooth contours to reduce drag.

Sheet metal parts were manually designed using cross-section drawings from which templates were made. These were then used by patternmakers to produce a wood pattern that subsequently was used to machine stamping dies with a milling machine that copied the pattern. Many different people were involved in the process which was susceptible to error at each step. By the early 1960s, NC machine tools were becoming more commonplace and a way was needed to economically generate the digital information to drive these devices.

One of the first techniques for mathematically describing surfaces, known as Coons patches, was developed by Steven Coons at MIT in the mid-1960s.[7] Another major center of surface definition research activity was in France. As early as 1958, Paul de Casteljau, working at Citroën, developed a mathematical approach for defining surfaces. Due to a perceived competitive advantage, Citroën did not

[7] Coons, Steven, *Project MAC-TR-41*, MIT 1967

 

disclose his work until 1974. By then, a number of academic and industrial researchers had moved on to implement other techniques.[8]

Around 1960, Pierre Bézier proposed to Renault's management that the company develop a method for mathematically defining automobile surfaces. By 1965 this work was well underway and by 1972, Renault was creating digital models and using the data to drive milling machines. The company called the system UNISURF and it eventually became an important component of Dassault Systèmes CATIA software (See Chapter 13). A key aspect of the work was the development of the well known Bézier curves and surfaces which are still used in many graphics applications. Bézier based his work, in part, on the earlier development of the Bernstein polynomials, introduced in 1911 by Sergi Bernstein.

The work of Rich Riesenfeld, Elaine Cohen, Robin Forest, Charles Lang, Ken Versprille and others led to the introduction of a number of other ways for defining curves and surfaces. The sequence of events went somewhat as follows. Coons was working with Ivan Sutherland (See Chapter 3) who had gathered together a group of very good mathematicians and programmers including Bob Sproul, Danny Cohen, Larry Roberts, and Ted Lee. At times it is somewhat confusing as to what went on at MIT and what work was done at Harvard University but suffice it to say that this group was instrumental in developing some of the early theory in the area of geometric modeling.

They were soon joined by Robin Forrest who was a graduate student in the Mathematical Laboratory at Cambridge University. During the summer of 1967, Coons and Forrest developed a technique for defining rational cubic forms. This was followed in 1969 by Forrest's Ph.D. thesis in which he defined methods for describing different graphic entities using the rational cubic form methodology.

A year later, Lee's Ph.D. work at Harvard extended Forrest's research to describe bicubic surface patches. Coons moved to Syracuse University in 1969 where he became Rich Risenfeld's Ph.D. thesis advisor. Risenfeld's described a new approach called B-splines in 1973.[9] (The term B-spline is derived from the term Basis Spline of which the Bernstein Basis is a special case.) During the 1970s, there was a constant flow of individuals between Syracuse, New York and Cambridge, Massachusetts. Eventually, the University of Utah became a player in this story when some of the Harvard and Syracuse people joined David Evans and Ivan Sutherland to focus on graphics applications.

Another Syracuse Ph.D. candidate at the time was Ken Versprille who was working on the definition of rational B-splines. He completed his Ph.D. thesis on the subject in 1975 prior to joining Computervision.[10] Versprille is credited by many people as being the developer of NURBS (Non-Uniform Rational B-Splines).

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[8] Bézier, Pierre – A *View of the CAD/CAM Development Period* – Annals of the History of Computing Volume 20, Number 2, 1998

[9] Risenfeld, Rich *Applications of B-Spline Approximation to Geometric Problems of CAD*, Ph.D. thesis, Syracuse University, February 1973

[10] Versprille, Kenneth J., *Computer-Aided Design Applications of the Rational B-Spline Approximation Form*, Ph.D. thesis, Syracuse University, February 1975

 

The next step at Syracuse was the work done by Lewis Knapp whose 1979 Ph.D. thesis was also a key building block in the evolution of NURBS.[11]

An additional step was the development of what became known as the Oslo Algorithms. In early 1979, Riesenfeld and his wife, Elaine Cohen, took a sabbatical from Utah to work with the CAD Group at the Central Institute, a research activity associated with the University of Oslo. Together with Tom Lyche, they defined a set of mathematical techniques that substantially enhanced the functionality of B-splines.

Significant work on surface definition techniques was also being done at a number of aircraft and automotive companies. Boeing was particularly active in the late 1970s and early 1980s working on surface geometry techniques based on this earlier academic research. One of the key developments at Boeing was the work James Ferguson did with cubic curves and bicubic surface patches.[12] Boeing was also one of the early proponents of IGES (Initial Graphics Exchange Specification) based on CAD system interoperability efforts it had underway at the time. In 1981, Boeing proposed that NURBS be added to IGES. This subsequently occurred in 1983.[13]

The development of NURBS technology has proven to be one of the key building blocks for advanced geometric modeling. As David Rogers, a professor at the United States Naval Academy, so eloquently puts it:

> "…with NURBS a modeling system can use a *single* internal representation of a wide range of curves and surfaces, from straight lines and flat planes to precise circles and spheres as well as intricate piecewise sculptured surfaces. Furthermore, NURBS allow these elements to easily be buried within a more general sculptured surface. This single characteristic of NURBS is key to developing a robust modeling system, be it for computer aided design of automobiles, aircraft, ships, shoes, shower shampoo bottles, etc. or for an animated character in the latest Hollywood production ……."[14]

A key observation needs to be made at this point. Much of the work going on in developing better surface definition techniques was being done at academic research centers and was typically published in widely available journals. Each researcher was, therefore, able to build on the work of those who had tackled earlier aspects of the problem. As seen by what occurred at Citroën, this would probably not have occurred if the work had primarily been done by industrial companies.

In regards to this latter issue, most automotive manufacturers were also working on internal surface geometry applications. Their major focus was in taking

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[11] Knapp, Lewis, *A Design Scheme Using Coons Surfaces With Nonuniform Basis B-Spline Curves*, Ph.D. thesis, Syracuse University, February 1979

[12] Ferguson, James C. *Multi-variable curve interpolation*, Journal of the ACM, Vol. 11, No. 2, 1964, Pg. 221-228

[13] Rogers, David F., *An Introduction to NURBS*, Academic Press, San Diego, 2001, Pg. 130

[14] Ibid, Preface

 

data points from full scale clay models and converting that information into digital surfaces that could be used to machine stamping dies.

**Moving from wireframe and surface geometry to solids modeling**

This subject could easily be a book in its own right and, in fact, a number of books on solids modeling have been written in recent years. Unfortunately most are filled with complex equations and diagrams that only a mathematician would appreciate. My intent is to try to put the evolution of solids modeling into more readable terms. It is interesting to note that there was little overlap between the individuals working on surface definition technology and the early proponents of solids modeling

There were a number of different research threads that eventually led to today's solid modeling technology.[15] One of the most important of these revolves around the activities of The CAD Group in Cambridge, England. Starting in the late 1960's, the efforts of this organization resulted in what is probably one of the more influential series of innovations and developments in the CAD industry. Basically, The CAD Group created the foundation for the three-dimensional solids modeling software that has been used as a technical building block by hundreds of CAD software companies and is used by millions of users worldwide today.

Determining where three-dimensional solid modeling started has proved almost impossible. Solid modeling research started in at least eight geographic locations independently of each other, almost all at the same time in the late 1960s and early 1970s. Even with activity and research being conducted around the world, no real usable product was available until the late 1970s and it really wasn't until the late 1980s that solids modeling became a commercial reality. However, many consider the first commercial product to be MAGI's SynthaVision which used primitive solids with high resolution rendering. Launched in 1972, SynthaVision is famous for its use in Walt Disney Productions' 1982 movie *TRON*, the first full-length animated feature film.

It was at the PROLAMAT Conference, held in Prague in 1973, that many of geographically disparate groups initially met – and started talking about this technology. At this conference, Ian Braid, from Cambridge's CAD Center, presented BUILD – using what is now called B-Rep or Boundary Representation technology. At the same event, Professor N. Okino from Hokkaido University, introduced TIPS-1, a CSG-based solid model program.[16] Also in attendance were Herbert Voelcker from the University of Rochester who was managing the PADL research activity, Professor Spur who was conducting research into solids modeling at the University of West Berlin, Dr. J. M Brun from University of Grenoble who masterminded Euclid (See Matra Datavision in Chapter 21) and others who helped drive the proliferation of solids modeling in following years.

The CAD Group at Cambridge was involved in this work far longer than any other organization. They developed technologies in the 1970s that are still being used (albeit using newer state-of-the-art programming techniques) today. ACIS (See Spatial Technology in Chapter 21), subsequently developed by this team, is currently used in

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[15] Particular thanks go to Rachael Taggart for help with this section as well as input from Charles Lang.
[16] CSG or Constructive Solid Geometry builds a solid model using primitive shapes such as cones and spheres and Boolean combinations of these basic elements. Boundary Representation of B-Rep models use surface definitions to describe the enclosed solid.

 

several million CAD seats. The same group also pioneered what became Parasolid, which supports another million or so CAD seats worldwide. None of the other solids modeling pioneers can boast of this type of track record.

Charles Lang graduated from Cambridge University in 1960 with a degree in engineering. After several years at Mullard Research in England, Lang enrolled as a graduate student at MIT in 1963 and worked at Project MAC for more than 18 months with Doug Ross and Steven Coons. Lang was then recruited back to Cambridge University's Computer laboratory by Professor Maurice Wilkes.

The British Government arranged funds and resources that underwrote the activities of the Cambridge CAD Group in 1965 – the group founded by Wilkes and headed by Lang until 1975. In 1969, the group started developing solid modeling software on a Digital PDP-7 system using assembly language programming. "Unfortunately no one told us it was impossible," says Lang. "But then Ian Braid turned up."[17]

In 1970, Ian Braid joined the group and focused on writing solid modeling code with particular attention to data structures. The result of his first thesis was BUILD1 – a solid modeling system presented at PROLOMAT – that used Boolean logic and simple solid geometry, grey-scale images and hidden line drawings. "BUILD1 had only planar and cylindrical surfaces implemented incompletely," according to Braid. "But it showed how one might interact with a solid model held in a computer and what could be done with it in changing or recording models, generating pictures, finding mass properties or in generating cutter paths."

Alan Grayer joined the team in the early 1970s, and by 1975 was generating NC tapes for 2½ axis milling machines. "This was the first time anybody automatically generated NC from a 3D model," says Lang. The Cambridge team regularly worked with Pierre Bézier at Renault as well as maintaining close relationships with MIT, Utah and Syracuse researchers.

According to Lang, funding for the Cambridge CAD Group started looking uncertain in 1974, and the team formed a company called Shape Data. Founders were Ian Braid, Alan Grayer, Peter Veenman and Charles Lang. "The company started without money and indeed, we never really formed it to make money," says Lang. "We started it to make the technology work." Shape Data was the first spin-off from the Cambridge CAD Group and according to Lang there have been nearly 90 spin-offs from the computer labs since. Peter Veenman started with the company full-time although the rest of the team remained with the CAD Group until 1980.

"Our original vision for Shape Data was based on a great relationship with Dave Evans – he knew modeling was much more fundamental than graphics and he had a vision of Evans & Sutherland being a one stop shop for people to get components to build 3D systems," Says Lang.

In 1978, Shape Data completed the industry's first commercial release of a solid modeling kernel – called Romulus. In 1980, Lang, Braid and Grayer joined Shape Data full-time. Then, in 1981 the company and its technology was acquired by Evans & Sutherland. In 1985, Lang, Braid and Grayer left the company and formed Three-Space

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[17] Quotes from Lang and Braid are based on telephone conversations and emails in mid-2004 with the author and Rachel Taggart.

 

Limited without a particularly clear idea of what they would do. Within several years, the team was hard at work on a new solids modeler – ACIS.

Simultaneously, Shape Data began work on creating Parasolid – a solid modeling kernel that was derived from the original Romulus work but used newer techniques and technologies.

As described in Chapter 21, Spatial Technology funded the early development of ACIS which was initially released in 1988. That same year Shape Data released Parasolid, and the company was acquired by McDonnell Douglas. In 1989, Parasolid was first used in a release of McDonnell Douglas' Unigraphics software.

Another significant center of solids modeling development was the Production Automation Project (PAP) at the University of Rochester. PAP was founded in 1972 by Herbert Voelcker who was a professor of electrical engineering at the time.[18] The intent was to develop automatic programming systems for NC machine tools. Voelcker was joined by Ari Requicha in 1973. The group soon redirected its activity to solids modeling and its first system, PADL-1 (Part & Assembly Description Language) was demonstrated at a CAM-I meeting in 1976 and made publicly available 15 months later. This was followed in 1981 by PADL-2. In addition to the normal contingent of graduate and undergraduate students, PAP also benefited from the assignment of engineers on loan from industrial companies that were interested in understanding this new technology.

The initial PADL-1 software used a combination of CSG and B-Rep techniques. The software was written in a derivative of FORTRAN and therefore was able to be ported between computer system fairly easily. The University of Rochester licensed the software in source code format for $1,200 to universities and $2,400 to commercial users. Licensees had virtually unlimited rights to the software. Between 1978 and 1985, the university issued 80 licenses. Fifteen years later, PADL-1 was still being used in academic institutions as a teaching tool. The PADL-2 project was launched in early 1979 with Chris Brown as the project director. Approximately $800,000 in funding was provided by ten industrial sponsors and the National Science Foundation. The intent was to be able to model 90 to 95 percent of unsculptured industrial parts. PADL-2 was also written in FORTRAN for portability reasons although this restricted the development team's ability to fully utilize newly evolving object-oriented programming techniques.

PADL-2 was initially distributed to the project sponsors in mid-1981. While organizations such as Sandia National Laboratory and Kodak used the software extensively for internal applications, most of the industrial sponsors did little with the software. An exception was McDonnell Douglas Automation which began the development of UNISOLIDS based on PADL-2 in 1981 and demonstrated the software at AUTOFACT in late 1982. Public distribution of PADL-2 began in mid-1982. License fees without the rights to redistribute the software varied from $600 for educational institutions to $20,000 for commercial concerns. Companies that wanted to build commercial solutions around PADL-2 were charged $50,000, the same amount paid by the initial sponsors. Between 1982 and 1987, Rochester issued 143 license agreements.

In 1987, the PAP was disbanded and the PADL technology and Voelcker moved to Cornell University which continued to distribute the software for a period of time. One

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[18] Voelcher, Herbert B. and Requicha, Aristides A. G., *Research in Solid Modeling at the University of Rochester: 1972-87*, chapter in *Fundamental Developments of Computer-Aided Geometric Modeling*, Edited by Les Piegel, Academic Press, San Diego, 1993

 

interesting development involved Cadetron which recoded PADL-2 in C for use on PCs. Cadetron was subsequently acquired by Autodesk where the software was marketed as AutoSolid.

**The basic structure of the CAD industry changes**

The decade of the 1980s was perhaps the most significant period regarding the evolution of the CAD industry. At the start of the decade, the industry was dominated by five companies – Applicon, Auto-trol Technology, Calma, Computervision and M&S Computing (Intergraph). Other companies starting to make themselves felt included McDonnell Douglas Automation, SDRC and IBM which was marketing Lockheed's CADAM software. Only Computervision and IBM manufactured their own computers but the other companies, except for SDRC, designed and built relatively expensive graphics terminals and other system components. For the most part, these turnkey systems vendors were manufacturing companies that happened to sell software. The industry's early profitability clearly revolved around manufacturing margins.

Two significant changes took place in the early 1980s. One was the transition from 16-bit minicomputers such as the Digital PDP-11 and Data General Nova 1200 to 32-bit super-minicomputers such as the Digital VAX 11/780. At the time, Digital clearly dominated this segment of the computer market. The other change taking place was the shift from Tektronix storage tube graphics terminals to color raster technology. In the latter case, this actually enabled the companies to manufacture a greater portion of their systems. All of the companies were engaged in major revisions to their software – in some cases a total rewrite of these systems.

In general, CAD systems circa 1980 sold for about $125,000 per seat or the equivalent to over $300,000 today. That was a lot of money when you realize that you can purchase Autodesk's Inventor Professional software and a moderately high performance PC for less than $10,000 today. Early systems often required an air-conditioned computer room. Even basic operator training took several weeks and, for most systems, it could easily be six months before they were back to a 1:1 productivity ratio.

Because these systems were relatively expensive they tended to be run on what is typically referred to as a "closed shop" basis. The systems were typically operated by individuals who spent full time working at the graphics consoles. Engineers and designers would bring work to the "CAD Department" and then come back hours or days later to received plotted output which they would carefully check. Marked up drawings would be returned to the CAD operators who would revise the drawings and return them once again to the requestor. It was a rare situation where an engineer was either allowed to use a system for interactive creative design work or sit with an operator and have that person directly respond to suggestions. The costly nature of these systems often resulted two, or even three shift, operation.

**A snapshot look at the industry**

In late 1982, Input, a market research firm then headquartered in Mountain View, California, prepared an in-depth analysis of the CAD industry for General Motors. This report was based on extensive interviews with both users and vendors. While I do not agree with all their findings, the report did highlight some key issues facing the industry and the user community at that time.

The lack of effective solids modeling was identified as a major constraint on industry growth. Enough research on the subject had been done by then to whet the appetite of users but workable solutions were still off in the future. The report also emphasized application integration or rather, the then current lack of solutions that integrated a variety of design and manufacturing applications. The need to tie database management tools into the application mix was also an urgent requirement.  Users particularly wanted more reliable software. These three issues were felt by respondents to be more important than ease of use and adequate service and education.

Key trends then underway included the transition to intelligent workstations, networking and the shift to color graphics. The need for color was reported to be a much higher priority in late 1982 than it had been in a similar study the firm did just a year earlier. The report also identified a major shift in costs that was already underway – hardware was becoming less expensive and software was becoming more costly. Input’s report did not spend much time discussing the stress this would put on current turnkey system vendors.

A portion of the report touched on the subject of user productivity. The authors pointed out that most companies were justifying the technology simply on drafting productivity and were not taking into consideration other elements of productivity including shorter product cycles and improved product quality. The inability of most vendors to expound on this issue was considered a drag on market acceptance of CAD technology.[19]

**Engineering workstations replace minicomputers**

One of the most significant hardware development in the 1980s was the introduction of the engineering workstation. Most CAD system vendors had been implementing more and more capability in their graphic terminals, offloading an increasing portion of graphic manipulation functions from the host computer. The engineering workstation took this one step farther and offloaded all application software execution as well. The minicomputer or mainframe host was now needed just for file management if at all and this was soon replaced by a specialized form the workstation called a server. The other key characteristic of these devices was that they could be networked together so that they could share data and even computer programs.

The first engineering workstation vendor was Apollo Computer, started by John (Bill) Puduska. The company’s early machines were more oriented towards software development but shortly after signing OEM customers such as Auto-trol and Calma as well as Mentor Graphics, a leading EDA vendor, Apollo began producing systems with good graphics capabilities. These early machines used Motorola 68000 microprocessors and their floating-point accelerators were reduced in size to just a single circuit board.

There were a number of advantages to workstation based CAD systems over the older minicomputer based products. First of all, the entry cost and the per seat cost was much lower. Prices quickly dropped to about $75,000 per seat and within a few years to under $50,000. In addition, performance was more predicable. When a company had six

[19] *Overview of the Computer-Aided Design and Manufacturing Engineering Marketplace,* Input, Mountain View, California, November 1982

 

or eight terminals hung off a VAX 11/780 and one user initiated a complex analysis task, the performance of all the other terminals suffered. If the host computer failed, all the terminals were inoperative. With engineering workstations, performance depended upon what the specific user did, not other operators, and if one workstation failed, the others were still operable.

Apollo’s workstations incorporated a significant amount of proprietary technology, particularly in regards to its operating system and networking. The AEGIS operating system was UNIX-like but it was not UNIX. The token-ring network was proven technology but it was not Ethernet which was rapidly emerging as a computer industry standard. Sun Microsystems was started just enough later than Apollo that it was able to use industry-standard UNIX software and Ethernet components. Sun was soon joined by Silicon Graphics or SGI as most people know it. SGI emphasized high-performance graphics but otherwise produced relatively standard workstations and servers.

Soon, the computer industry exploded with perhaps 20 or more manufacturers of engineering workstations. They were often referred to as JAWS (Just Another Workstation System). Most never really got off the ground and soon faded from sight. The major computer manufacturers were a different story. Companies such as IBM, Hewlett-Packard and Digital realized that these workstations were a competitive threat and they introduced similar products. IBM’s RS/6000 was a respectable product but HP and Digital struggled to gain momentum in this area. Digital never really established significant market share. HP solved its problem by acquiring Apollo in 1989.

As described in later chapters, the early industry leaders struggled in making the transition to industry standard workstation hardware and becoming more of software and services businesses. The fundamental problem was that they each had made significant investments in manufacturing facilities and personnel and now were faced with the problem of unwinding that business. This was not easy. Some like Auto-trol tried to maintain a manufacturing focus by repackaging its Apollo workstations in the same terminal configurations it had used earlier. There was no easy way out and it led to the eventual downfall of all the early leaders except Intergraph.

Meanwhile a new group of vendors gained significant market share. Key among them was IBM teamed up initially with Lockheed’s CADAM Inc. and later with Dassault Systèmes, McDonnell Douglas Automation which eventually morphed into UGS, SDRC and two newcomers, Autodesk and Parametric Technology, both of which are described below.

As the price of CAD systems came down, changes in how they were used also began to occur. While many organizations continued to operate CAD departments, other began to disperse systems into their design and manufacturing organizations. Instead of providing sketches to a professional CAD operator, design engineers were trained to do this work themselves. This became increasingly significant as new versions of the software enabled users to create drawings as a byproduct of the design process. The basic organizational structure of design teams began to change as companies adapted to the quickly evolving technology.

**The personal computer becomes the new wild card**

 

By 1987, vendors of traditional CAD systems had sold about 100,000 seats of software and the equipment to support these users. It had taken them 17 years to do so. In just five years, the new PC software vendors installed a like number of seats.[20] Today there are literally millions of CAD users, the vast majority working at PCs.

Personal computers actually predate the engineering workstation described above. The early machines were more collections of components for the computer hobbyist than serious technical tools. This began to change in August 1981 when IBM introduced its first PC, the Model 5150, which came with 16KB of memory, an alphanumeric display and no hard disk drive. But it only cost $1,995. The key decisions on the part of IBM were to use an Intel microprocessor, a 4.7 MHz 8088, and a new operating system from a small company in Seattle, Microsoft. As the familiar line goes – the rest is history.

It took some time before IBM PC-compatible machines had the performance and graphics capability to handle CAD software. Initially, the few companies such as T&W Systems (see Chapter 20) that were providing PC software worked with similarly priced computers such as the Apple II or more expensive machines such as Terak 8510. There were also a fair number of custom systems that people were experimenting with. Prior to starting Autodesk, John Walker and Dan Drake built PCs using Texas Instruments' 9900 microprocessor and Mike Riddle provided some of the software for these PCs using the CP/M operating system from Digital Research.

Over the next few years, Intel churned out a series of increasingly powerful microprocessors and math-coprocessors and third party vendors began offering graphics accelerator cards that could be plugged into a PC by a dealer or even tech savvy users. In 1983 Autodesk sold nearly 1,000 copies of AutoCAD worth about $1 million. There were a number of issues that separated the PC CAD market from that of the major vendors who were mostly in the midst of making the transition from being systems manufacturers to selling industry standard workstations and software.

- The concept was to sell 80 percent of the functionality of the larger systems for 20 percent of the cost. In reality, early versions of software such as AutoCAD and VersaCAD had much less than 80 percent of the capabilities in Computervision's CADDS 4, Intergraph's IGDS or Auto-trol's Series 5000.
- The PC software vendors did not try to do everything themselves. Third party software vendors who added application capabilities to the product were encouraged while the legacy vendors discouraged such activity by controlling access to the key programming tools used with their systems.
- This was a software only business.
- The software was sold through dealers who made most of their money selling hardware and by providing training services.
- Users called the dealer for technical support, not the software vendor.

Throughout the mid-1980s, the turnkey vendors treated the emerging PC market as something they wished would simply go away. Their sales people downplayed the capabilities of PCs and continued to push their own "big boy" solutions. By 1986

[20] Machover, Carl, *MicroCAD Trends – 1980/1990*, 4th Annual International Forum on Microbased CAD, September 23, 1987, North Carolina State University

 

Autodesk was doing over $50 million in annual revenue and these companies finally realized they had a fight on their hands.

The larger vendors took two approaches. Some ported a subset of their software to the PC, others created their own alternative to AutoCAD while several added UNIX co-processors to PCs and attempted to use the same software they ran on engineering workstations. In all cases, these were considered secondary products to the companies' mainstream systems.

A major inflection point occurred in mid-1993 when Microsoft introduced Windows NT. This made it much easier to support both UNIX and Windows versions of the same software and fairly soon all the vendors were offering Windows NT versions of their software. Although most charged the same whether the software ran on a UNIX workstation or a Windows NT PC, the hardware portion of a typical PC system was less than half that of an engineering workstation.

The PCs still were at a performance disadvantage, but the gap was closing rapidly, especially after Intel launched the Pentium microprocessor in mid-1995. Over the next decade, PCs became the primary platform for most CAD users with UNIX workstations relegated to specialty applications. PC performance is no longer an issue. In 12 years, Pentium clock speed has increased from 133 MHz to nearly 4.0 GHz, typical memory has gone from 256KB to over 1GB and graphic performance exceeds that of workstations costing over $100,000 in 1995. All this for just a few thousand dollars.

Substantially higher performance can be expected in the future. By late 2006, some PCs were equipped with microprocessors than contain dual or quad computing elements. Chips with eight, sixteen or more processing elements were expected over the next several years. CAD software, of course, has to be adapted to use this advanced processing capability.

### Transition to feature-based parametric design

Parametric Technology Corporation (see Chapter 16) shook up the CAD industry in late 1987 when the company introduced a feature-based parametric modeling package called Pro/ENGINEER. While the software had some technical gaps, it demonstrated especially well and numerous companies began pilot installations in order to compare this new technology to the existing legacy systems most were using at the time. Other than Dassault Systèmes and SDRC, PTC's competitors were all going through the difficult transition away from manufacturing and/or marketing computer hardware. Unexpectedly, they were faced with making a major software change at the same time if they were to retain their existing customers.

While PTC did not necessarily invent all the concepts incorporated into Pro/ENGINEER, they did an excellent job of packaging and marketing the technology. Fairly quickly, the company began taking business away from the other vendors, especially Computervision. During the next five or six years, PTC's competitors added feature-based design and parametric capabilities to their mainstream packages with varying degrees of success. UGS, SDRC and Dassault did a good job making the transition while Applicon, Computervision and Auto-trol Technology soon faded from the scene. Eventually, even SDRC could not make it as an independent company and was acquired by UGS.

 

**The emergence of mid-range systems**

As the PC gained momentum as the CAD platform of choice, a new generation of CAD systems began to evolve. Usually referred to as mid-range systems to distinguish them from older legacy systems, they had several advantages over the older systems. This software was developed both by new start-up such as SolidWorks (see Chapter 18) and by established companies including Computervision and Intergraph. The mid-range systems differed both in the underlying technology and in how they were marketed.

- These systems were implemented strictly to execute on PCs running Windows.
- They used component software technology, especially for geometric modeling and constraint management.
- They focused on design and, to a lesser extent, drafting, and left other applications such as NC and analysis to third party partners.
- Like PC-based systems, the mid-range systems were predominately sold by dealers. The difference was that the vendors provided greater technical support.
- Typical software prices were between $3,000 and $6,000 per seat or about a quarter of the price being charged for full-function systems in the mid-1990s.

Over time, mid-range systems have somewhat merged with the full function systems although there are still some distinct differences. Dassault acquired SolidWorks and UGS acquired Intergraph's Solid Edge business unit. Autodesk entered the fray with Inventor and PTC repackaged Pro/ENGINEER in order to be more competitive in this space.

**Where are we today**

As explained in subsequent chapters, significant industry consolidation began to occur around the mid-1990s and continues as this is written. The major vendors now see themselves as offering more than just CAD and document management. The current term that describes the overall industry is Product Lifecycle Management or PLM. It is a $10 billion plus industry just for the software involved and there are literally millions of users of these tools. It has totally changed how engineering design is practiced and has been a major element in the increase in industrial productivity we have seen during the past decade.

In very simple terms, virtually no product, building, electronic component or system or factory is designed today in a developed country without the use of this technology. It has resulted in more reliable products that are less expensive to produce and are more attractive to potential customers. It has changed technical education and to a significant extent, the practice of numerous professions. Design engineers do analysis today that a few years ago was only done by highly specialized professionals. On the other side of the equations, drafting is rapidly going away as a profession as the new generation of design programs produce drawings as a byproduct of the design process and in many cases new designs are placed into production with few, if any, drawings.

In the past, there was a persistent battle between the desire to implement new software techniques and the performance of available computers. That has changed in recent years as the performance of low-cost computers has exploded. During the past 40 years, price/performance ratios of available systems have increased by a factor of a million and there is no indication that the pace is slowing. If anything it is accelerating. Software has become much more robust – there are few design problems that cannot be readily handled today.

The major problem remaining is applying the technology to increasingly complex projects. That means managing massive amounts of design data – a task some companies are doing well while others are struggling. Airbus S.A.S. has incurred a multi-year delay in launching the A380 super-jumbo aircraft due to data incompatibility problems between its German and French operations. Meanwhile, Boeing's launch of the 787 Dreamliner is staying on schedule even though its design and manufacturing is scattered around the world. The bottom line is that CAD is phenomenal technology that is revolutionizing engineering design and manufacturing, especially when used right.

# Chapter 3

# Computer-Aided Design's Strong Roots at MIT

During World War II, the Massachusetts Institute of Technology became a significant research and development partner with the United States military establishment in Washington. One such activity was the Servomechanism Laboratory which was founded in 1940 by Professor Gordon Brown who would eventually become dean of the Institute's school of engineering. Jay Forrester, a key participant in what follows, enrolled at MIT in 1939 as a graduate student was soon involved in the Lab's efforts to develop feedback control mechanisms for military equipment such as shipboard radars and gun mounts. During the war, this activity took Forrester to the South Pacific where he spent time on the aircraft carrier Lexington helping to repair prototype radar systems. While Forrester was on board the Lexington, it was torpedoed but not sunk.

**Whirlwind - test bed for key technologies**

In 1944, the Servomechanism Laboratory or the Servo Lab as it was typically referred to, began working on the development of computer systems in support of the Navy's Airplane Stability and Control Analyzer (ASCA) project under a $75,000 contract. The objective was to create a general purpose flight simulator as compared to the then current practice of building custom flight simulators for each aircraft type. At the time, most simulation work involved analog computers and this was the initial plan for ASCA. By 1946, Forrester became convinced that digital computers along the lines of the ENIAC machine which had recently been completed at the University of Pennsylvania, would provide a better platform for aircraft simulation. This led to the establishment of Project Whirlwind with the objective of building MIT's first digital computer, Whirlwind I. There never was a Whirlwind II and most references to the I were dropped by 1950 or so.[1]

Within a couple of years, work on ASCA was shelved and the group's focus was to build the world fastest and most reliable digital computer. Whirlwind is important to the development of Computer-Aided Design (CAD) technology for several reasons. Because of the original intent to use this computer as the control element for a flight simulator, it was designed from the start to be capable of real-time operations. In turn, this led to the utilization of interactive devices for operator communication with the computer. One such device was a Cathode Ray Tube (CRT) display console as shown in Figure 3.1. This early interest in display technology would eventually lead to the development of more advanced graphics terminals by MIT's Lincoln Laboratory, a successor to the Institute's Digital Computer Laboratory, as part of the TX-0 and TX-2 computer systems described below.

In developing Whirlwind, Forrester and his assistant, Robert Everett, had to tackle two major issues. The first was how to achieve substantially better system reliability with

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3.1 [1] *Funding a Revolution: Government Support for Computing Research* - Computer Science and Telecommunications Board, 1999 a computer that utilized many thousands of relatively unreliable vacuum tubes. The concept they came up with was to use a marginal checking technique where engineers could vary the system's voltages to detect vacuum tubes that were on the verge of failing. It added substantial complexity to the computer but enabled Whirlwind to operate for long periods without problems.

The second issue was what to use for the computer's main memory. ENIAC had just 20 words of memory that was fashioned out of the same vacuum tubes used for the rest of the system. This was totally inadequate for Whirlwind's intended purposes. The design goal was to have 2,048 words of 16-bit memory. The initial system configuration utilized electrostatic storage tubes. These proved to be difficult to fabricate and Whirlwind initially began operation with just 256 words of internal memory. The memory was later increased to 1,024 words. In early 1949, Forrester began experimenting with magnetic core memories. While the concept was relatively straightforward, finding the appropriate material that had the magnetic properties they were looking for took several years. In retrospect, the development of magnetic core memory by the Whirlwind design team was probably its most significant accomplishment even though we are more interested in its graphics capabilities.

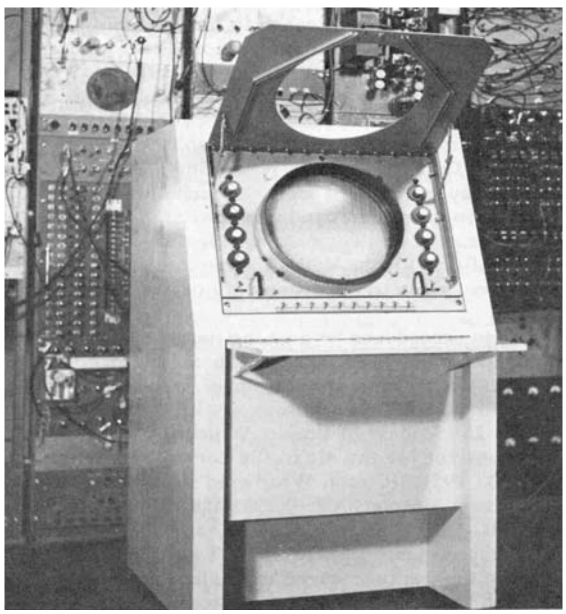

Figure 3.1
16-inch Whirlwind Display Console[2]

In 1947, the group within the Servomechanisms Laboratory working on Project Whirlwind became the Lab's Electronic Computer Division and in 1951 it became the MIT Digital Computer Laboratory, independent of the Servo Lab. During these years Forrester continued as both the Whirlwind project director and director of the Computer

[2] Redmond, Kent C. and Smith, Thomas M. – *Project Whirlwind: The History of a Computer Pioneer* – Digital Press, 1980 pg. 192

Laboratory with Everett as the associate director. Other key players who eventually played important roles in this story included Ken Olsen (founder of Digital Equipment Corporation), Norm Taylor (vice president of ITEK and leader of that company's development of the Electronic Drafting Machine – EDM described in Chapter 6), and Charles Adams and Jack Gilmore (co-founders of Adams Associates and instrumental in the development of the EDM). Forrester would go on to become a professor at MIT's Sloan School of Management while Everett would eventually become president of MITRE Corporation.

Whirlwind was a physically imposing machines as illustrated in Figure 3.2. It took up 2,500 square feet of space on the third floor of the Barta Building, just north of the main MIT campus. The machine's circuitry consisted of 12,500 vacuum tubes which consumed 150,000 watts of electricity. Whirlwind was assembled in a series of large racks which provided easy access to the machine's circuitry, facilitating maintenance and modification of what was essentially a research machine. Most of the physical equipment was fabricated by Sylvania Electric Products Company which was located in Boston at

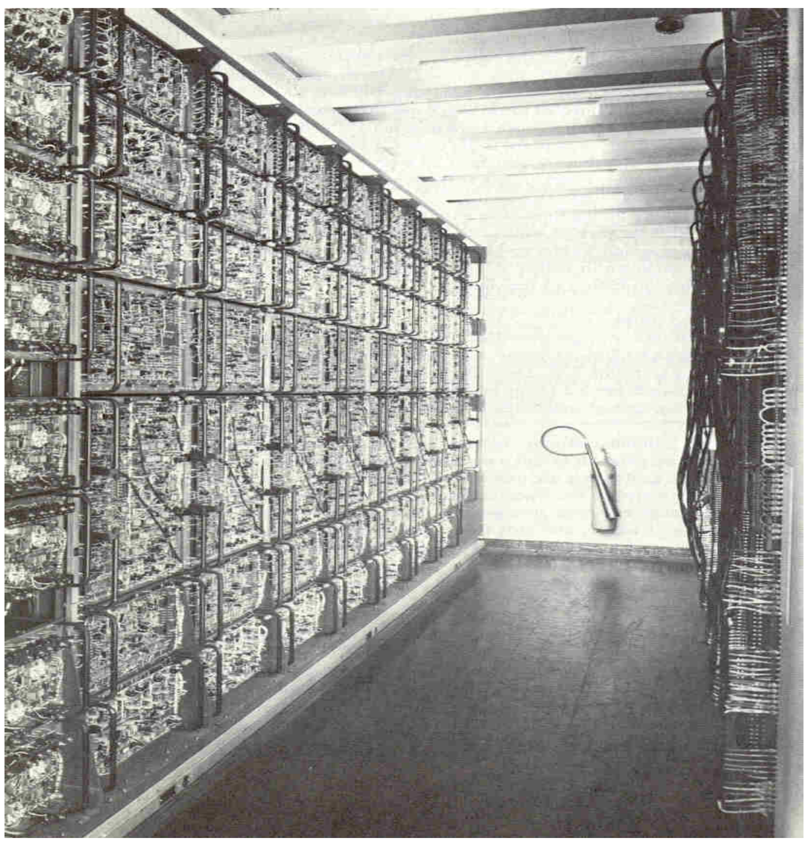

Figure 3.2
Whirlwind Arithmetic Unit (Approximately one tenth of the total computer system)[3]

[3] Ibid pg. 248

that time. It is hard to determine exactly when Whirlwind became operational. For practical purposes the best date is probably March 1951 although some productive work was done as early as the third quarter of 1949.

Computational performance was impressive for the time. The system had two clock speeds, 1 MHz and 2 MHz, which resulted in 20,000 operations per second. While many early computers handled data in a serial manner, Whirlwind transferred data and instruction words internally in a parallel fashion – all 16 bits at the same time. The computer was capable of supporting up to 32 different commands but only 27 were implemented.[4] While slow by today's standards, Whirlwind continued to provide valuable computational services to the MIT community until it was decommissioned in 1959.

After sitting idle for several years, it was moved in 1963 to Wolf Research & Development in West Concord, Massachusetts where it continued in operation until the early 1970s when it was permanently shut down. Overall, the Navy and Air Force spent about $5 million developing Whirlwind. As described in detail in *Project Whirlwind: The History of a Computer Pioneer* by Redmond and Smith, the relationship between the Whirlwind development team and the Navy was often quite rocky and there were several points in time when the Navy was close to shutting off the funding for this project. If it had done so, the history of the CAD industry might have turned out far different than it did.

During most of the 1950s, efforts surrounding Whirlwind focused on supporting the Air Force's SAGE (Semiautomatic Ground Environment) air defense system. The actual SAGE computers, which began deployment in 1958, were built by IBM utilizing design concepts derived from Whirlwind. A byproduct of the SAGE project was the establishment of MIT's Lincoln Laboratory, located in Bedford, MA, about 15 miles west of the Institute's Cambridge campus. Lincoln Lab is important to this story in that it was the initial home of the TX-0 computer, a second generation Whirlwind system, and the permanent home of the TX-2 computer. The latter computer was used extensively as a graphics research platform throughout the 1960s. The Computer Lab became Division 6 of Lincoln Lab with Forrester as its director from 1951 to 1956. Everett took over the division at that point and managed it until 1959 when he left to help start MITRE Corporation.

Forrester was very perceptive in seeing where the development of computer technology was leading. As early as 1948 he described remote access of computers similar to the time-sharing methods of the 1960s and the use of the Internet today.[5]

## Graphics programming with Whirlwind

Programming early computers was done at the lowest level of the machine's binary command and memory addressing structure. Several research centers realized that better techniques could be developed. One of these groups was a Whirlwind programming team led by Charles Adams. Adams delivered a paper at the 1952 meeting of the Association of Computing Machinery where he said "Ideally, one would like a procedure in which the mathematical formulation together with the initial conditions can

[4] Ibid pg. 240
[5] Ibid pg. 232

simply be set down in words and symbols and then solved directly by a computer without further programming."[6]

According to Herman Goldstine:

> "At the same meeting John Carr described the programming work at the Massachusetts Institute of Technology. It is clear that the Whirlwind group there was very alive to the needs of the programmer. Adams and J. T. Gilmore[7] extended the ideas of Wilkes, Wheeler, and Gill, and there evolved from this symbolic address procedure, an idea that seems to have been independently created by Rochester and his colleagues at IBM. The Whirlwind group also pioneered in the development of a so-called interpretive algebraic coding system. ..."[8]

From its earliest existence, Whirlwind had some form of graphics display attached. The earliest device could display just 256 points of light. This was subsequently expanded to 4,096 or a 64 by 64 matrix. Substantially less than the 1280 by 1024 or greater resolution used by contemporary graphics systems. Adams wrote a short program that displayed a bouncing ball on the display. This was done by solving three simultaneous differential equations. A little later, probably in late 1950, Adams and Gilmore wrote the first computer game. It consisted of trying to get the ball to go through a hole in the floor by changing the frequency of the calculations.

Meanwhile, Everett developed the first version of the light gun, the predecessor to the light pen, that could be used to identify specific displayed points on the CRT. The first engineering design application on Whirlwind was probably done by a masters thesis student, Dom Combelec, who wrote a program to help design antenna arrays.[9]

**Development of NC machine tools and APT**

The wartime control feedback work of the Servomechanisms Laboratory involved military equipment that utilized continuous or analog signals to control devices such as radar antennas and anti-aircraft guns. By 1949, the theoretical foundation was being developed to control servo mechanisms using digital or pulse data. In the spring of that year, Gordon Brown received a telephone call from John T. Parsons, Jr. of the Parsons Corporation's Aircraft Division in Traverse City, Michigan. Parsons was looking for a device that could accept digital data and drive a machine tool.[10]

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[6] Adams, Charles W. – *Small Problems on Large Computers*- Proceeding of the ACM, 1952 pg.101

[7] Adams and Jack Gilmore would go on to establish one of the first computer software consulting firms in the country in 1959. In 1961, they initiated the development of a prototype CAD systems under contract to Itek Corporation working with Norm Taylor who had been instrumental in the early Whirlwind activity and subsequently was a senior manager on the SAGE project. See Chapter 6.

[8] Goldstine, Herman – *The Computer: From Pascal to von Neumann* – Princeton University Press, 1972 pg. 338. In a private communication, Gilmore told me that he and Adams briefed IBM's Nat Rochester on the concept shortly after Gilmore came up with it and that the concept was not developed independently at IBM.

[9] Taylor, Norman H., *Retrospectives I: The Early Years in Computer Graphics*, SIGGRAPH '88 Panel Proceedings

[10] Reintjes, J. Francis – *Numerical Control: Making a New Technology* – Oxford University Press, 1991 pg. 16

The common practice at the time for machining complex surfaces was to drill closely spaced holes to a predetermined depth and then to finish the part either by carefully machining the surface or manually filing. The Air Force was beginning to develop a series of high-speed fighter aircraft and needed better methods to machine parts to high tolerances. Parsons had negotiated a contract with the Air Force to develop a machine to do this but he lacked the technical resources to accomplish the project. The result was a three-way arrangement between Parsons, the Air Force and MIT.

The initial Servo Lab project leader was William Pease assisted by James McDonough. They quickly recognized that a comprehensive multi-axis machining technique was preferred over the technique of simply drilling closely spaced holes. The initial idea was that a data record (the plan was to use punch cards for inputting this data) would be read for each increment the tool would move. With a positional resolution of 0.0005 inches, this would have required a card reader far faster than anything then available and a huge volume of punch cards for even the simplest part. The concept that evolved at MIT was to provide a command for the machine to go to a specific point in three-dimensional space and then have a controller mechanism that would feed pulse data to the motors that controlled each axis of the machine tool.[11] The basic ideas developed by Pease and McDonough is fundamentally how it is still done today.

Actual implementation of these concepts began in earnest in July, 1950. One of the new Servo Lab staff members working under McDonough was Herbert Grossimon.[12] The Air Force provided the Servo Lab with a three-axis Cincinnati Milling Hydro-Tel milling machine which was subsequently equipped with the appropriate control devices for each axis and interfaced to a vacuum tube NC controller. Machining commands were read from punched paper tape instead of punch cards. The experimental machine tool was up and running in March 1952.[13] A formal introduction of the first NC machine tool was held at MIT on September 15-17, 1952. The total cost to the Air Force for the Servo Lab's work on developing NC to this point came to just $360,000.[14]

Preparing control tapes for early NC machine tools was a time-consuming manual process. By the time the first NC machine tool was introduced, it was recognized that unless the process of producing these tapes could be substantially improved, the overall economics of using NC would suffer. The first work in trying to automate the process was done by John H. Runyon on Whirlwind using a subroutine technique. This was followed by Arnold Siegel's efforts in developing a procedural language for programming machine tools. Using Segal's software, a part that had taken eight hours to program by hand was done on Whirlwind in less than 15 minutes.[15]

A major effort to develop a more advanced part programming solution was undertaken in 1956 by Doug Ross who had joined the Lab's staff several years earlier. A

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[11] Reintjes, J. Francis – *Numerical Control: Making a New Technology* – Oxford University Press, 1991 pg. 34

[12] In 1956, McDonough and Grossimon left MIT and founded Concord Control to build NC controllers. The company subsequently developed a series of specialized plotters and digitizers. One such device was a plot-back digitizer in 1968. The Concord Control project manager was Philippe Villers who shortly thereafter co-founded Computervision. See Chapter 12.

[13] Reintjes, J. Francis – *Numerical Control: Making a New Technology* – Oxford University Press, 1991 pg. 43

[14] Ibid p. 47

[15] Ibid p. 78

Computer Applications Group was established within the Lab with Ross as its head and with John Ward assigned the task of acting project engineer for the development of what eventually became the Automatically Programmed Tool (APT) system. Ward was subsequently replaced by Donald Clements as permanent APT project administrator.

APT was a fairly significant undertaking that involved substantial participation by a number of large industrial companies, particularly those in the aerospace industry under the auspices of the Aircraft Industries Association (AIA is now known as the Aerospace Industries Association). These companies did not simply provide funding support - rather they actively participated in the development of the APT software.

One method they developed that is still used was the concept of preparing NC information in a generalized form and then post-processing that information for specific combinations of machine tools and controllers. By the mid-1950s it was obvious that the machine tool manufacturers were not interested in building the controllers themselves and that these would be built by companies such as Bendix and General Electric that had more expertise in the field of electronics.

Ross felt that Siegel's approach did not go far enough and that a more comprehensive part programming language was needed. He wanted something where the part programming could be done using English-like statements and could be done by someone who was not a computer programmer. His work on APT resulted in a long-term personal commitment to the development of tools that would bridge the gap between engineers and the computer. According to J. Francis Reintjes:

> "He envisioned programming in general as an interrelational process between human and computer in which a general purpose computer would, in effect, be turned into a special purpose machine through use of a set of special programs developed to deal with whatever problem was at hand. The human would then work back and forth with the computer, in a conversation-like mode."[16]

The first version of APT developed by the Servo Lab team under Ross and its industry partners was a two-dimensional implementation that utilized curved boundary lines. It was called 2D-APT-II. Nine aircraft companies and IBM worked with MIT on this implementation. Most of the early programming work was done on IBM 704 computers which all the aircraft manufacturers had access to. MIT had not yet installed the 704 it had on order and its work continued to be done on Whirlwind. 2D-APT-II was ready for initial field testing on April 30, 1958. This was a rather complex application with the documentation taking six volumes and running to 517 pages.[17]

Once 2D-APT-II was completed, the Servo Lab began phasing out of APT development and moving on to more generalized CAD development. Ross and his people continued to work on some of the core mathematical routines but the bulk of the development initially moved to the AIA's Central Project Group in San Diego and then, in 1962, to the Illinois Institute of Technology Research Institute (known today as Alion Science and Technology) which took over the long term support of APT - subsequently referred to as APT-III. IITRI, under the leadership of Dr. S. Hori, continued to provide

[16] Ibid pg. 81
[17] Ibid pg. 87

APT support through the mid-1970s. An early aluminum alloy forging machined using APT III to program the NC milling machine is shown in Figure 3.3. Not only did this single machined piece replaced an assembly of over 250 sheet metal parts but the resulting aircraft component was stronger, more reliable and cost less to produce.[18]

Work on establishing APT as an international standard began in 1963 under the auspices of the USASI X3.4.7 Subcommittee. Since APT had been implemented on the assumption that user organizations would be able to add company or project-specific functionality to the core software, establishing a standard was a complex task. If every conceivable function was included, the standard would have been unwieldy and possibly impossible for many computer companies to implement. On the other hand, an overly

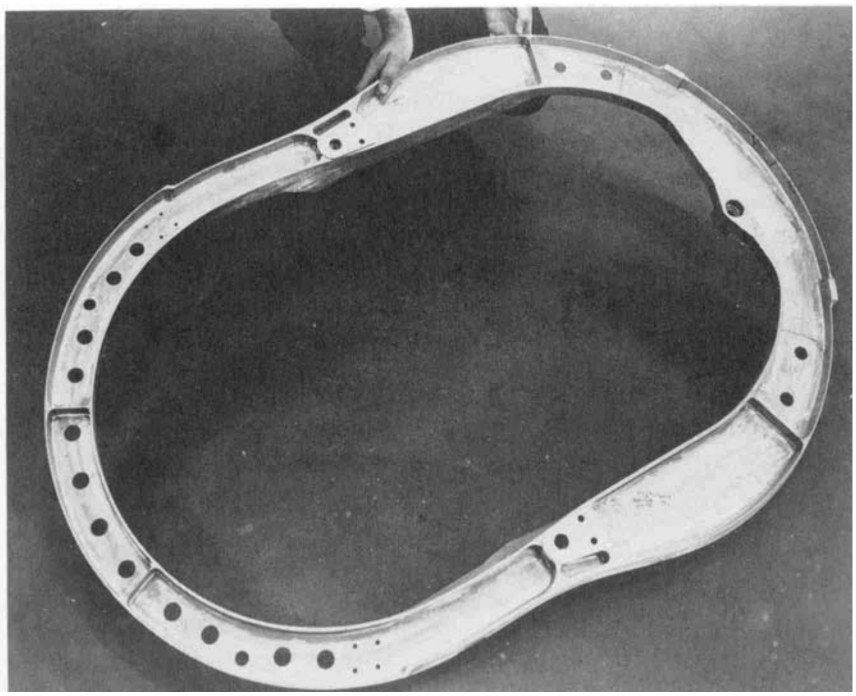

Figure 3.3
Aluminum Alloy Forging Machined Using APT III[19]

limited subset would have equally impractical. The solution was to define five subsets where each subset incorporated all the features of lower level subsets. The five levels were :

1. Multi-axis contouring system
2. 3D contouring system
3. Minimum contouring system
4. Advanced point-to-point system
5. Minimum system

Specific sets of special-purpose features implemented by various groups were categorized as “modular features” with the ability of a user to plug the modular feature into a core

[18] Ibid pg. 89
[19] Ibid pg. 90

subset. As of 1968 there were 25 such modular features being considered by the X3.4.7 Subcommittee.[20]

APT was eventually implemented on a number of large mainframe computer systems. Among the many different versions were APT 360 developed by IBM, 6400/6600 APT developed by Control Data Corporation, and UCC APT developed by University Computing Corporation. Some companies including General Electric developed their own in-house implementations of APT. While these different implementations all basically conformed to the APT standard, each version had its own idiosyncrasies. In the late-1970s, IBM launched a new version of APT for the 370 series of computers called APT-AC where AC stood for Advanced Contouring. Today, there are probably still several hundred organizations, mostly aerospace companies and large machine shops, using APT with the primary source of support coming from Austin NC Corporation, the group that previously was the APT support team at University Computing. The latest versions run under the UNIX and Windows operating systems.[21]

### Moving on to new research

An offspring of the original Servomechanisms Laboratory at MIT in the early 1950s was the Dynamic Analysis and Control Laboratory (DACL) which worked on the research and development of components for air-to-air missiles. In 1952, Robert W. Mann joined DACL as the head of its Design Division. Mann had worked as a draftsman before the war for Bell Telephone Laboratories and had returned there after serving in the Army Signal Corps. Under the G.I. Bill he was able to attend MIT and earn both a Bachelor's and Master's degree in mechanical engineering in four years. Shortly after taking on the design management role with DACL, Mann was asked to join the MIT Mechanical Engineering faculty to teach design.

As readers will see in succeeding pages, the history of the CAD industry is replete with personal relationships and chance meetings that took place at MIT. Mann's undergraduate roommate was Kenneth Olsen, the future founder of Digital Equipment Corporation, who worked with Forrester on the development of Whirlwind's magnetic core memory. Olsen was responsible for the development of a specialized variant of Whirlwind called the Memory Test Computer. Mann's future wife, Margaret Florencourt, was also part of the Whirlwind team.

Within MIT's Mechanical Engineering Department, a major change took place in 1953. At that time the Institute restructured its undergraduate curriculum, eliminating the requirement that all freshman take a required course in drawing and descriptive geometry. The faculty teaching this course, including Steven Anson Coons, were merged into the department's Design Division. Coons had received his bachelor's degree from MIT in 1932 and had worked for a number of years as a mathematician and designer for Chance-Vought Aircraft. Coons would eventually become world-known for his work in developing surface definition concepts used throughout the CAD industry.[22]

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[20] Feldman, Clarence G. – *Subsets and modular features of standard APT* - Proceedings of the 1968 Fall Joint Computer Conference, San Francisco, California. 1968 Volume 33, Thompson Books, pg. 67

[21] Telephone conversation with Ven Sudhaker on June 20, 2003. Sudhaker had been involved for many years with UCC's activities in this area and was currently with Austin NC.

[22] Robert W. Mann - *Fundamental Developments of Computer-Aided Geometric Modeling* – Chapter 16 *Compute-Aided Design – 1959 through 1965 – In the Design and Graphics Division of MIT's Mechanical Engineering Department,* 1993

 

**Getting the CAD ball rolling at MIT**

In January 1959, an informal meeting was held involving individuals from both the Electronic Systems Laboratory (the new name for the former Servomechanisms Laboratory) and the Mechanical Engineering Department's Design Division. They concluded that there was a significant opportunity for digital computers to be used to automate engineering design activities. The ESL contract with the Air Force for the development and support of APT was scheduled to terminate in about a year and Reintjes and his staff were eager to find a new area in which to channel their resources.[23]

It is interesting to note that as early as 1959 the question about whether or not mechanical drawings would be needed in the future was already being discussed by ESL personnel. It would take over 30 years before design engineers would feel comfortable transferring three-dimensional models of parts to manufacturing organizations for production without the necessity of accompanying those electronic files with paper drawings.

The January meeting led to a series of seminars, the first of which was held in April, 1959. Among those in attendance were Reintjes and Ross representing ESL and Mann and Coons representing the Mechanical Engineering Department. Also involved on the Mechanical Engineering Department side was Dwight Baumann who had joined DACL after receiving his bachelor's degree from North Dakota State University and was then working as an instructor in the Design Division. A second seminar was held in May. Perhaps the most significant development resulting from these seminars was the definition of the effort as Computer-Aided Design rather than Computerized Design or Computer Automated Design. Mann in particular thought that the addition of the hyphen was particularly significant.[24] The point being that the computer can assist engineers in creating designs but cannot replace them.

According to Reintjes, by the spring of 1959 they had a fairly good idea of what the general tasks should initially be in developing a viable Computer-Aided Design system.

> "…a critical analysis of what roles the computer should play for creative design; the development of a system of programs for the creative design process; and an investigation of requirements for a workstation that would serve as the interface between the designer and the design tool – the general purpose computer."[25]

At this early stage of development, these tasks were rephrased as:

- How does a design engineer enter operational commands and spatial information into the computer?
- How is the design information presented back to the engineer?
- How is the information stored internally in the computer system?
- What design and drafting functions need to be implemented?

[23] J. Francis Reintjes – *Numerical Control- Making a New Technology,* 1991
[24] Robert Mann (item cited)
[25] J. Francis Reintjes – *Numerical Control- Making a New Technology,* 1991

 

We sometimes forget that modern computer systems and applications are built on top of the technology that has come before. Today, a personal computer costing less than $1,000 comes with a mouse for input, a high performance color display, a functionally rich operating system, communication tools, a document scanner, a large quantity of main memory and disk storage, a graphical printer and a wide variety of application software. Virtually none of this existed in 1959 and what did exist was expensive and difficult to access.

In December 1959, the Air Force issued a one year contract to ESL in the amount of $223,000 to fund what became known as the Computer-Aided Design Project. Included in the contract was $20,800 for 104 hours of computer time at $200 per hour. In 1959 that was a lot of money. Newly graduated engineers were making perhaps $500 to $600 per month at the time.

Much of the work on the Air Force contract was done by graduate students working on masters and Ph.D. theses. One of these students was Richard Parmelee who focused on using the computer for stress analysis. According to Reintjes, Mann, Coons and Parmelee saw excellent possibilities for the computer in stress analysis:

> "…..because it was hoped that, through the use of a computer, many more checkpoints on stress could be analyzed quickly and economically. Since hand calculation was long, tedious, and often only approximate, the conventional design tendency was to limit the number of calculations to locations deemed critical in light of the designer's judgment and experience."[26]

One conclusion Parmelee reached in preparing his master's thesis was that a stress analysis capability would need to be compatible with the many other functions that would be required by a complete CAD system. This was the start of the concept of a fully integrated design capability where individual programs would feed data to other modules and use the data they created by still other modules.

The then high cost of computer resources limited the flexibility the project team had in exploring avenues of research and required them to use whatever resources they did have as efficiently as possible. Another graduate student, Joe Purvis, Jr. looked at the issue of storing and retrieving standard component data. One major problem he faced was the high cost of data storage at that time. A 10MB storage unit cost about $60,000 per year to lease (most large-scale computer systems were leased at the time rather than purchased outright) as compared to a 300GB disk drive which costs less than $100 to purchase today.

The key point to be made here is that in 1959 and 1960 the researchers at MIT were already looking at the right issues even if the computer technology had not yet advanced sufficiently to support their ideas.

**Focus on large computers**

The Computer-Aided Design Project being run by ESL and the Mechanical Engineering Department focused, for the most part, on using large mainframe computers. Typically these systems were run by professional operators and programmers had little

[26] Ibid, Pg. 103

opportunity to gain hands-on experience with them. This was a different approach than what was being followed across the campus in the Civil Engineering Department where, under the leadership of Professor Charles Miller, software development for highway design applications was initially being done on an IBM 650 located in Boston followed by an IBM 1620 installed on campus. With these machines, the programmer was the operator. On the other-hand, these machines provided no on-line graphics capability.

Initially, ESL used Whirlwind extensively for tasks such as developing the APT NC part programming language. By the late 1950s, that machine was becoming costly to support and it was phased out for general work by 1958. This forced the Lab to shift its activity to the Institute's Computation Center run by Dr. Phillip Morse, Professor of Physics. The center had an IBM 709[27] mainframe which was only available eight hours per day. The other 16 hours were split between other New England universities and IBM's own work. In 1962, the vacuum tube 709 was replaced by a transistorized mainframe computer, an IBM 7090. Although somewhat faster than the 709, the 7090 still could not keep up with the workload.

The demand for computer resources was so great that instead of returning the 709 to IBM when the 7090 was installed, the Institute purchased it outright and installed it in a separate facility run by Professor John Slater, Professor of Physics. This machine was operated on a fee-for-service basis and was used extensively by the CAD Project. Probably more important was the fact that the TX-0 computer at Lincoln Laboratory had been replaced by the far larger TX-2 in 1959 and was basically surplus. The TX-0 was transferred to the Research Laboratory of Electronics and was subsequently used extensively by the CAD Project, especially for work on interactive workstations.

TX-0 was originally built by Lincoln Lab as a test bed for building transistorized computers. The team responsible for this machine was led by Ken Olsen. It was an 18-bit machine that contained 3,500 transistors at a time when they cost $80 each. Initially, TX-0 had a 64K word magnetic core memory but when it was turned over to ESL, this memory was removed to be used in the TX-2 and a smaller 4K memory was installed. The machine was capable of 83,000 add/subtract type operations per second. Because the machine was intended primarily as a test bed for transistorized design, it had a fairly limited instruction repertoire.

The TX-0 had a CRT display designed by Ben Gurley and a light pen designed by Wesley Clark. The availability of this machine and its graphics terminal complemented the CAD Project's use of the MIT Computation Center's mainframe machine. Olsen went on to start Digital Equipment Corporation in 1957 and the company's first computer, the PDP-1, had many similarities to the TX-0 but a more extensive set of commands.

In 1963, MIT's IBM 7090 was replaced by a 7094 system. For the first time, the Computation Center was able to offer time-sharing services, greatly improving access to the Center's resources. Development of this system was under the direction of Dr. Fernando Corbató. The software, the development of which had started on the 709 and continued on the 7090, was called the Compatible Time Sharing System (CTSS) and it could support 30 users at one time.[28]

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[27] The IBM 709 replaced an IBM 704 which was in use at MIT for a relatively short period of time.

[28] Corbató, Fernando J. et al – *An Experimental Time-Sharing System* - Proceedings of the Spring Joint Computer Conference, San Francisco, California 1962 Vol. 21 – Spartan Books, pg. 335

Corbató's time-sharing work on the 7090 at the Computation Center led, in 1963, to the establishment of Project MAC, funded by the Department of Defense's Advanced Research Projects Agency (ARPA). Under Dr. Robert Fano, Professor of Electrical Engineering, Project MAC implemented an advanced version of CTSS called MULTICS (Multiplexed Information and Computing Service). The software ran on a modified General Electric 635 computer subsequently marketed as the GE 645. It took until 1968 before MULTICS became available on the GE 645 and it was eventually used extensively for CAD research in the late-1960s and during the 1970s.

**Formalizing data structures for CAD systems**

After completing the 2D-APT-II system, Ross and his team of programmers continued working on improving the mathematical calculation portion of the APT system. This software was called ARELEM (Arithmetic Element) and was key to future versions of APT. The work covered the period from 1960 to 1962. During the same time frame, Ross began establishing a theoretical framework for CAD software. One of the key issues was how to store data so that one geometric element could link to one or more other elements in the design database. Some of his ideas started germinating as early as April 1959 when Ross presented a paper at an MIT Symbolic Manipulation Conference. He subsequently published an extensive paper on this subject at the 1963 Spring Joint Computer Conference with Jorge E. Rodriquez as co-author that proposed a data structure that would be insensitive to where in the CAD model an operator selected an item for further action. Ross and Rodriquez emphasized that users of CAD applications need not be aware of the internal data structure of the applications they would be using.[29] An expanded version of this architecture was used by Ivan Sutherland in developing the Sketchpad system described below.

Ross' work on APT along with his initial design of a CAD system data architecture led him to conceptualize a comprehensive software environment for implementing engineering design software. Called AED for Automated Engineering Design, it was intended to be a generalized problem solving system that would require a new and non-traditional programming language. Ross settled on using a modified form of ALGOL-60 for AED programming. It is interesting to note that Ross was focused on "automated design" while Mann and Reintjes had earlier made an issue of the fact that it was to be computer-aided design. As mentioned above, Mann was adamant about the hyphen in the term.

AED eventually involved tens of man-years of programming effort. In typical Ross style, AED was described as a generalized methodology that consisted of four primary components; a lexical processor that would break down input statements into their basic components, a parsing processor that grouped these basic components into meaningful operations, a modeling processor that extracted meaning from these statements and created relevant data and an analysis processor that actually carried out the solution to the problem as defined.[30] As the reader can see, AED was conceptualized

[29] Ross, Douglas T. and Rodriquez, Jorge E. – *Theoretical Foundations for the Computer-Aided Design System* - Proceedings of the Spring Joint Computer Conference, Detroit, Michigan 1963 Vol. 23 – Spartan Books pg. 305

[30] Reintjes, J. Francis – *Numerical Control- Making a New Technology,* 1991 p. 118

as a general problem solution methodology and was not necessarily limited to mechanical engineering problems.

This was an ambitious undertaking, perhaps too ambitious. The generalization of AED was driven by tables – changing the nature of a problem to be solved was expected to simply require the formulation of new tables. A initial version of AED called AED-0 was up and running on the MIT Project MAC time-sharing system sometime in 1963. In addition to using the software for mechanical design applications funded by the Air Force, ESL also undertook the development of several electrical and electronic design applications under a $40,000 research grant from NASA.

Ross had plans for a more powerful version of AED called AED-1 but lacked the financial wherewithal to accomplish the task with just MIT's resources. ESL took the same approach it had with the development of APT and solicited support from industry participants in December, 1963. By the following March, six experienced programmers were on board from a group of aerospace firms for one year assignments at MIT. A seventh from IBM joined later that year. Instead of working on AED-1, however, the team spent most of its efforts enhancing AED-0 and implementing batch versions for IBM 709, 7090 and 7094 mainframe computers as well as expanding the time-sharing version. This development effort took about a year and the upgraded version of AED-0 was released to interested companies in March 1965.

**Development of the light pen and display terminals**

Obviously, if a computer system were to be developed that would enable engineers to interactively create technical designs, a method was needed to input graphical information and to view that data. The first reference to the need for a visual display device that I found was in a memorandum written in 1945 by John von Neuman.

> "In many cases the output really desired is not digital (presumably printed) but pictorial (graphed). In such situations the machine should graph it directly, especially because graphing can be done electronically and hence more quickly than printing. The natural output in such a case is an oscilloscope, i.e. a picture on its florescent screen. In some cases these pictures are wanted for permanent storage (i.e. they should be photographed); in others only visual inspection is desired. Both alternatives should be provided for."[31]

The first practical use of an oscilloscope or CRT as a graphical output device was likely in conjunction with MIT's Whirlwind in the early 1950s. At one point it was shown on an Edward R. Morrow television show, *See It Now*, with Jack Gilmore participating in the demonstration.[32]

There were two types of CRT displays in use at this time. One type displayed an image in the form of a pattern of dots while the other type created an image by drawing straight line segments between pairs of points. With the latter type of device, often

[31] von Neumann, John – *Memorandum on the Program of the High-Speed Computer Project*, November 8, 1945 as quoted by Herman Goldstine in *The Computer- from Pascal to von Neumann,* 1972 Princeton University Press pg. 242

[32] *The Story of Computer Graphics,* ACM SIGGRAPH Video 1999.

referred to as a stroked display, curves and circular arcs were displayed as series of short vectors. Most CRT displays were not persistent, meaning that unless the image was refreshed continuously, it would quickly fade away. Typically, the image had to be regenerated 30 or more times per second in order to avoid having the image flicker. The data for refreshing the image was stored either in the computer memory, on a secondary storage device such as a magnetic drum or disk or in a dedicated memory built into the display terminal itself. It fairly quickly became obvious that stroked displays were preferable for CAD applications since they could create higher quality and more complex images, but they were more expensive than point displays.

Figure 3.4
Use of a Light Gun by a SAGE Operator[33]

Given that a CRT was to be used for graphical output, the next issue was how to input commands and graphical information. Typewriters, pushbuttons and rheostat dials were all in use for various applications by the early 1960s and they were utilized by many early CAD developers. None of these devices were effective tools for inputting graphical information or for selecting previously created graphical elements. SAGE used a light gun, invented by Bob Everett, for this purpose. It sensed light on the CRT screen and caused a computer interrupt to occur. The device sensed the initial burst of light caused when the electrons first stuck the phosphor on the back of the CRT screen. This process occurred in just a few microseconds, but it was enough time that the computer could identify the specific graphical item that had been pointed to. A trigger mechanism was used to activate the light gun. Otherwise, the photosensitive pick-up element in the gun would sense random light and would cause false signals to be sent to the computer. Light

[33] Redmond, Kent C. – *From Whirlwind to Mitre: The R&D Story of the SAGE Air Defense System* – 2000, MIT Press pg. 436

guns, which were the size and shape of an automatic pistol, were used extensively in the SAGE system as shown in Figure 3.4.

The light gun was an effective device when used as a component in an air defense system such as SAGE but was rather awkward to use for scientific and engineering applications. An ergonomically more attractive device called a light pen was designed at MIT's Lincoln Laboratory for use with the TX-0 and later TX-2 computers. When the TX-0 was transferred to the MIT campus in 1958, a CRT display and light pen were part of the configuration. The light pen was the size and shape of a large fountain pen with a shutter button replacing the light gun's trigger. The initial version, which had been designed by Ben Gurley at Lincoln Lab, was improved upon by the ESL staff under the direction of John Ward. The major problem with the original light pen was that CRT tubes at the time were substantially curved (the flat screens we are familiar with today are a fairly recent development) and were covered by a protective plate. The result was that the distance from the tip of the light pen to the actual CRT screen (the side with the phosphor) was as much as two inches. This made it difficult to resolve small items displayed on the screen.

The original work done at Lincoln Lab on both light pens and CRT displays was well documented by Robert Stotz in a paper presented at the 1963 Spring Joint Computer Conference. Stotz, who worked with Ross at MIT, pointed out that a key graphics design issue was what work should be done by special purpose graphics hardware and what work should be done by the computer the device is attached to.[34]

Ward redesigned the light pen with a small focusing lens in front of the photo diode sensing element. The redesigned pen was about 5/8 inch in diameter and seven inches long. According to Reintjes, the new light pen was used on the ESL Display Console associated with Project MAC and Ward was asked to produce similar pens by more than a dozen other research organizations, requests which ESL responded to. A diagram of the redesigned light pen is shown in Figure 3.5. One interesting connection is the fact that the member of ESL's staff responsible for supervising the operation of TX-0 from 1958 to 1959 was Earl W. Pughe, Jr. Pughe subsequently went to work for Itek Corporation and was responsible for much of the hardware engineering on that company's Electronic Drafting Machine including its light pen.

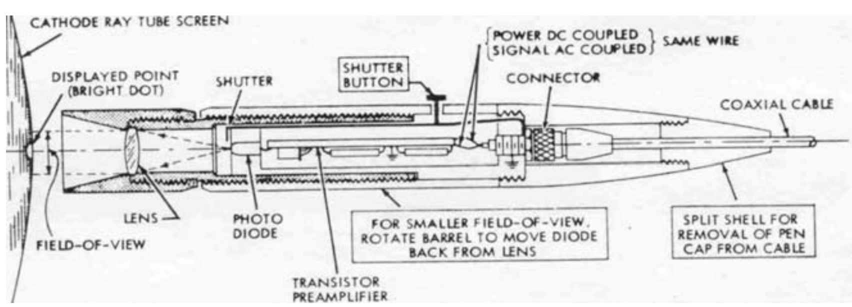


Figure 3.5
ESL's Advanced Light Pen[35]

[34] Stotz, Robert – *Man-Machine Console Facilities for Computer-Aided Design* - Proceedings of the Spring Joint Computer Conference, Detroit, Michigan 1963 Vol. 23 – Spartan Books pg. 327
[35] Reintjes, J. Francis – *Numerical Control – Making a New Technology* – Oxford, 1991 pg. 113

One of the key aspects of the TX-0 computer once it had been transferred to the MIT campus was that students and research associates could sign up to use the machine for a maximum of one hour at a time. This was one of the few places where someone working on a software problem could have an entire machine for their own use. Nearly everyone else on the MIT campus had to work with batch mainframes – not particularly conducive for developing interactive software.

**Early graphics activity at Lincoln Laboratory**

In 1955, MIT Lincoln Laboratory established an Advanced Computer Research Group headed by William Papian with Wes Clark responsible for logical design and software and Ken Olsen responsible for circuitry and computer production. One of the group's first projects was the previously mentioned TX-0 computer. The first computer to use transistor circuitry, TX-0 was built primarily to test the circuitry and core memory destined to be used in the TX-2 computer. This machine was equipped with a CRT display and light-pen.

Jack Gilmore, who had left the Whirlwind project in 1952 to become a Navy pilot, returned in 1956 and joined Clark's logical design team. He subsequently developed an on-line operating system that provided programmers with the ability to sit at the computer's console and debug and modify programs using an IBM typewriter and CRT display. It was a new concept in that most on-line program debugging until then was done at the machine code level using console lights and switches.

A combination of CRT display, on-line keyboard and light pen was used by Gilmore to build a utility program so that programmers could debug programs using flow charts on the display with logical switches that could be opened and closed during the debugging session. One of the first TX-0 graphic applications was a pattern recognition algorithm that examined EEG brain wave data fed into the TX-0 via an analog to digital converter.

The demand for utilizing scientific symbols in TX-0 applications led Clark to initiate a project in 1957 to design and build a work station (subsequently called the MIT Lincoln Writer) that would enable programmer scientists to use scientific symbols in their programs and output results to the CRT display as well as a printer.

Ironically, this project led to the first use of interactive text editing and graphics. The need to design a scientific set of a symbols that could be used to represent a complete set of alpha numeric symbols and characters led the team to build a program to simulate a scientific work station. The light pen was used to design individual combination of spots that formed the characters and a simulated keyboard consisting of 200 keys was displayed on the lower half of the display as 200 individual points. A plastic overlay was used with the anticipated symbols labeled above each key point. The result was a program, primarily written by Gilmore, called "Scopewriter."

One task Gilmore undertook was to simulate a typewriter which resulted in what was perhaps the first interactive text editor. In the process of building symbols, they found that they could create electronic symbols and geometric figures and they were used to create simple circuit diagrams and flow charts. Gilmore summarized this effort at a 1988 SIGGRAPH conference.

> "….what I believe the TX-0 really contributed was an online interactive man machine communication environment. We didn't really think about the fact that we were doing anything particularly impressive in the area of graphics, but we were trying to switch from a batch processing orientation to an interactive situation where programmers actually worked at a console and made changes right there on the spot."[36]

In 1959, Gilmore wrote an assembly program on the TX-2 for a programming language based on the alphanumeric and scientific character set of the Scopewriter. He left Lincoln Lab in October of 1959 and with Charles W. Adams, co-founded one of the earliest software consulting firms, Charles W. Adams Associates Inc. Gilmore's Lincoln Lab staff position was filled by Ivan Sutherland.[37]

**Sketchpad – The project that got the world excited about interactive design**

The activity that has received more credit than any other for launching the use of interactive graphics for engineering design and drafting was Ivan Sutherland's Sketchpad project developed using Lincoln Laboratory's TX-2 computer. The terminal consisted of a CRT display, a light pen, a set of push buttons, a panel of toggle switches and four dials that were used to change the size and position of the displayed image. See Figure 3.6. The TX-2 was also interfaced to a PACE plotter built by Electronic Associates.[38]

TX-2 was a powerful 36-bit computer that had earlier served as the prototype for the IBM machines built for the Air Force's SAGE project. Images were displayed on the graphics display in the form of a series of dots with a resolution of ten bits in each axis. These dots were displayed at the rate of 100,000 per second. To avoid flicker which occurred at 30 frames per second or less, an individual image was limited to about 3,000 dots. The coordinates of the dots to be displayed were stored in a table in the main memory of the TX-2 computer, enabling the Sketchpad application software to proceed independently from display operations.[39]

A light pen was used to select elements already being displayed or to indicate a new location on the screen. In the later case, the user would point to a symbol constantly displayed on the screen, in the case of Sketchpad it was the word "INK," and then drag a displayed cursor to the desired location. Light pen operations were terminated by flicking the pen. Since the computer could no longer determine that the light pen was sensing light, it would conclude that the operation was completed. Rotary dials allowed the user to display images at a wide range of scales.

Functional commands were entered using the terminals pushbuttons. To draw a line from an existing point to a new location, the user would aim the light pen at the existing line, press the "LINE" pushbutton, move the light pen to the location of the line's second endpoint and then flick the light pen to indicate that the operation was completed. The line ended up as a straight line irrespective of the path the user followed

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[36] Gilmore, John T., *Retrospectives II: The Early Years in Computer Graphics*, SIGGRAPH '88 Panel Proceedings

[37] See Chapter 6 for a discussion of graphics work undertaken by Adams Associates in partnership with Itek Corporation.

[38] Sutherland, Ivan E. – *Sketchpad: A Man-Machine Graphical Communication System* - Proceedings of the Spring Joint Computer Conference, Detroit, Michigan, 1963 Vol. 23 – Spartan Books pg. 329

[39] Ibid pg. 334

to go from the initial point to the final point. The toggle switches were used to set specific modes of operation such as whether or not to display certain types of information.

Figure 3.6
Ivan Sutherland seated at the TX-2 display terminal[40]

A key aspect of Sketchpad was the use of the previously mentioned data file structure developed by Ross, somewhat extended by Sutherland. In his 1963 Spring Joint Computer Conference paper, Sutherland described it as a ring structure since the string of pointers eventually closes back on itself. This data structure enabled a Sketchpad user to insert new elements arbitrarily anywhere in the displayed drawing, to remove elements and have the software close the logical gap created by that operation, to merge several data files and to perform auxiliary operations on the data in either forward or reverse order.[41]

Each spot displayed on the CRT screen was stored in the previously mention display table in the form of a 36-bit word. Twenty bits were used to define the X and Y coordinates of the spot while the other 16 bits of the 36-bit word were used to point to the element that caused that point to be added to the display table. When the user pointed to a displayed line, circle or arc on the CRT screen, the computer could tell which spot in the display table was being sensed by the light pen. Since the display table word contained a pointer back into the ring-organized data table, the software could immediately identify the graphical element the user was pointing to.

The two features of Sketchpad that most impressed me were its ability to support nested symbols and its ability to support geometric constraints. Any group of geometric elements could be combined together to form a symbol (over the years these groupings would be called by many other names such as cells and blocks). This symbol could then be placed wherever the user desired at different sizes and different orientations. Specific locations of a symbol could be defined as an attachment point for other elements. This was particularly useful when using the system to create electrical schematic diagrams.

[40] Ibid pg. 329
[41] Ibid pg. 333

The software allowed constraints to be applied or removed from geometric elements after the elements had been initially constructed. As an example, lines could be made parallel to each other, defined to be vertical or horizontal, set to the same length and locked, one element to another. If two lines were defined as being parallel and then one line was defined as being horizontal or at some other angle, the second line would move accordingly, maintaining the parallel constraint. This was well before the concept of parametric design became popular.

While Sketchpad was a significant technical accomplishment, this success needs to be put in the context of the computer system available to support the software. TX-2 was a huge machine (I remember literally walking through it on a visit to Lincoln Lab) that cost the Air Force millions to build. Sketchpad used a substantial amount of the computer's resources when operating. As a consequence, it was not viewed at the time as putting legions of drafters out of work in the near future. Sutherland summed it up fairly well:

> "For drawings where motion of the drawing, or analysis of a drawn problem is of value to the user, Sketchpad excels. For highly repetitive drawings or drawings where accuracy is required, Sketchpad is sufficiently faster than conventional techniques to be worthwhile. For drawings which merely communicate with shops, it is probably better to use conventional paper and pencil."[42]

In his 1963 Spring Joint Computer Conference article Sutherland goes on to describe several applications where he felt the value of using interactive graphics was particularly significant. Large repetitive patterns that would have taken two days to do manually were done in less than an hour including the time it took to plot the results. One example was the use of Sketchpad to produce a binary coded decimal encoder where the layout had to be plotted to high accuracy. Sutherland liked the idea of using Sketchpad to analyze mechanical linkages, an application which would not become widespread for several decades. He also demonstrated using Sketchpad to do bridge stress analysis on TX-2 and suggested that the analysis of electrical circuits was also an attractive application. Finally, he stated that the system's ability to make moving drawings opened up the possibility of using it for making animated cartoons. Very prescient but somewhat ahead of its time.

Sutherland concluded that:

> "The circuit experience points out the most important fact about Sketchpad drawings. It is only worthwhile to make drawings on the computer if you need something more out of the drawing than just a drawing….. We are as yet a long way from being able to produce routine drawings economically with the computer."[43]

It would be another six years before Applicon and Computervision would begin delivering commercial CAD systems that did in fact produce drawing economically.

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[42] Ibid pg. 341
[43] Ibid pg. 344

Sutherland eventually moved to the University of Utah where he worked with David Evans and the two co-founded Evans& Sutherland, an important computer graphics firm. In 1989, he was awarded the "Turing Award" by the Association of Computing Machinery for his work on Sketchpad.

**Tim Johnson gives Sketchpad three dimensions**

Timothy Johnson was a research assistant working for Doug Ross on the Air Force-sponsored CAD Project being undertaken by the MIT Mechanical Engineering department and the Institute's Electronic Systems Laboratory. His work, as reported in the Proceedings of the 1963 Spring Joint Computer Conference, was to extend the two-dimensional Sketchpad system to three dimensions. The resulting software, also developed on Lincoln Laboratory's TX-2 computer, is usually referred to as Sketchpad III.

Sketchpad III was the first computer-based graphics system to implement the traditional three orthogonal views of a three-dimensional object together with a perspective view of that object. The perspective view could be at a different scale from the other views. This layout was a result of Johnson's determination that users were uncomfortable sketching in perspective and that a more traditional drafting methodology using orthogonal views was needed.[44] Johnson used the same graphics display and light pen as did Sutherland. As with Sketchpad, pushbuttons were used to indicate what action was to be taken with the graphical element the user pointed to with the light pen such as erasing the item, moving it or using that location to start a new line or arc.

Rotary dials were used somewhat differently than with the initial Sketchpad program. In addition to magnifying and rotating the drawing, one dial was used to change the perspective view by modifying the point at which lines converged. Graphical elements created in one view of the object were immediately displayed in the other views. The model was rotated by selecting one of the views with the light pen and then turning one of the rotary dials on the display console. New graphic images of all three orthographic views and the perspective views were generated continuously as the dial was rotated and the resulting image displayed on the CRT screen. [45]

To create a new element in other than one of the orthogonal planes simply required the user to rotate the model until the plane of interest was parallel to the plane of the CRT display. This technique was subsequently used by many commercial CAD systems. Sketchpad III also started moving this technology more towards being a fairly complete design solution. Utility routines were developed for storing three-dimensional data on magnetic tape and plotting hard copy drawings. These routines were written by Leonard Hantman who subsequently went to work at Adams Associates where he managed a number of computer graphics projects.

The technique for displaying perspective views with hidden lines removed was developed by Larry Roberts[46] as part of his Ph.D. thesis. Initially Roberts wrote software

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[44] Johnson, Timothy – *Sketchpad III: A Computer Program for Drawing in Three Dimensions* - Proceedings of the Spring Joint Computer Conference, Detroit, Michigan, 1963 Vol. 23 – Spartan Books pg. 348

[45] Ibid pg. 349

[46] Roberts is best known for his work in developing ARPANET, the forerunner to the Internet as we know it today. Roberts was also the founder and CEO of Telenet, the first packet switching company as well as CEO of a number of other communications companies.

on the TX-2 that took digitized photographs of three dimension objects and detected the edges of the object in three-dimension space. This led to the first software that did hidden line elimination. Roberts wanted to create perspective views without hidden lines but could find no documented techniques for combining matrix techniques with generating perspective views. He actually went back to some of the early German textbooks on descriptive geometry in order to solve this problem.[47]

I remember visiting Lincoln Lab sometime in the latter part of 1964 or early 1965 for a demonstration of Sketchpad III where the operator (probably Tim Johnson) retrieved a model of a building and then demonstrated how the model could be rotated (with hidden lines removed) to the point where the viewer was inside the model looking out the front door. In his paper on Sketchpad III, Johnson listed as future research subjects the ability to define arbitrary surfaces, determine the intersection of surface in three-dimensional space, determine edges hidden by visual surfaces and satisfy general graphical constraints.[48]

**General Motor's DAC-1**

Like most large automobile manufacturers, General Motors was extremely interested in determining the extent to which computer graphics could be used to improve vehicle design. Starting in the late 1950s General Motors Research (GMR) began work on a research project called DAC-1 where DAC stood for Design Augmented by Computers.[49] Prototype work involved the use of an IBM 704 mainframe computer equipped with a Model 780 display. The DAC-1 project leader at GM's Research Laboratories (GMR) was Edwin Jacks. Fred Krull, who was involved in CAD-related activity at GM for over 30 years, was also a key member of the team.

Contrary to what has often been published, DAC-1 was not initially conceived to be a computer-based design and drafting system along the lines of Sutherland's Sketchpad or Itek's Electronic Drafting Machine although it eventually evolved to have many of the same capabilities. In 1964, when a series of papers were presented at that year's Fall Joint Computer Conference, the system was really a hardware test facility used to support research in computer graphics. Jacks outlined four areas of concern regarding using computer graphics in automotive design:

1. The need to be able to work with existing drawings. The computer system had to be able to read existing drawings as well as produce some form of graphical output. This led to the incorporation of a device to scan 35 millimeter film as well as a high-resolution CRT to produce film output.
2. Once data was scanned into the system, tools were needed to manipulate the data. The thinking at GM revolved around the need for several individuals to view the data and collaboratively decide

[47] Roberts, Lawrence G., *Retrospectives II: The Early Years in Computer Graphics,* SIGGRAPH '88 Panel Proceedings
[48] Johnson, Timothy – *Sketchpad III: A Computer Program for Drawing in Three Dimensions* - Proceedings of the Spring Joint Computer Conference, Detroit, Michigan, 1963 Vol. 23 – Spartan Books pg. 353
[49] The project was initially simply called "Digital Design."

what changes should be made and then to graphically make those changes to the data.

3. There was also a need to compare graphical data. A typical example would be comparing the roof line of a new model to the prior year's model.
4. In addition to graphical information, an engineering design system had to support textual information.[50]

The general philosophy at GM was summed up in 1994 in an article on the history of DAC-1 by Krull. "It was felt that, if a computer could read sketches and drawings, then it could be programmed to produce further drawings, engineering data, and control tapes for numerically controlled machine tools."[51] Initial development of these techniques was done on the IBM 704 computer using simple cubic polynomials to describe the outlines of components such as automobile hoods. GMR personnel developed surface interpolation techniques that preceded Steven Coon's work at MIT by several years. The resulting surface outline was output to the 780 display device.

Subsequent to proving the feasibility of these concepts on the 704 computer, GMR and IBM entered into a multi-million dollar joint development project in November 1960 to create the DAC-1 hardware configuration. The system, based on GMR's specifications, took 30 months to complete. It was built around an IBM 7090 mainframe with 32K words[52] (each word was 36 bits in length) of main memory. This was subsequently upgraded to a 7094 Model II with a 64K memory. The DAC-1 configuration required the design and construction of several specialized hardware components including a special data channel, a display adapter, a display unit, a photo-recorder-projector and a photo scanner. Some of this equipment was based on work IBM had previously undertaken as part of the SAGE air defense project described earlier.

Substantial programming effort was spent in modifying IBM's standard operating system so that the 7094 could handle both batch and real time programs at the same time. In order to understand what GMR was attempting to do, the reader needs to appreciate that this expensive computer configuration was supporting just a single graphics terminal.

While most real time systems were being programmed in assembly language in the early 1960s, the DAC-1 software was written using NOMAD, a customized version of MAD, the Michigan Algorithmic Decoder, which in turn, was based on ALGOL 58. FORTRAN was rejected as a programming language since at that time it could not handle bit manipulations nor could it handle interactive selection of subroutines for execution.

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[50] Jacks, Edwin L., – *A Laboratory for the Study of Graphical Man-Machine Communications* - Proceedings of the Fall Joint Computer Conference, San Francisco, California 1964 Vol. 26 – Spartan Books pg. 343

[51] Krull, Fred N., *The Origin of Computer Graphics within General Motors*, IEEE Annals of the History of Computing, Vol 16, No.3, 1994

[52] Krull's paper in the *Annals of the History of Computing* repeatedly uses the term 32-Kbyte memory. I believe this statement is inaccurate and that it was a 32 K word memory.

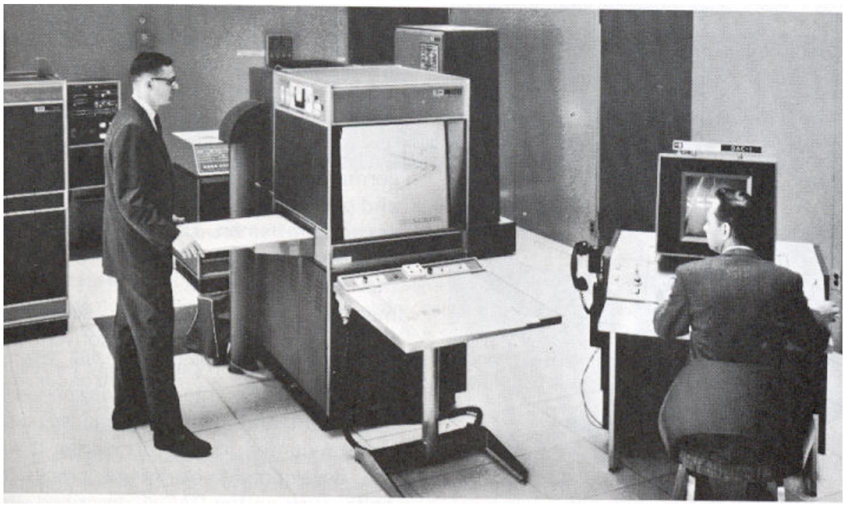

Figure 3.7
DAC-1 Hardware Configuration with Photo Scanner/Recorder at Center

The primary application implemented by 1964 was the scanning of drawing images from film, viewing and manipulated the scanned images on a CRT display and then producing copies of the revised images on film. The display terminal had a position-indicating pencil that functioned quite differently than the light pen which was used with other interactive systems of that era. Rather than sensing light, it utilized a conductive surface on the face of the display monitor to determine the location the user was pointing to.


Figure 3.8
DAC-1 Console

GMR programmers developed software that could take curve data or coordinate values describing surfaces and create an internal model of the surfaces. They also produced software that would take this three-dimensional data and prepare control tapes for driving NC machine tools.

 

It became apparent fairly quickly that scanning hard copy design data was not an effective approach to entering this information into the computer. GMR programmers began experimenting with an approach that involved using the console's function box with overlays indicating the task that a particular button would initiate. If the action required the selection of an existing item on the display, the operator would pick it with the electronic pencil. Contrary to subsequent experience at Lockheed with its CADAM software, GM engineers objected to the ergonomics involved with pointing to the screen with the pencil.

The DAC-1 hardware was the precursor to the Alpine system subsequently developed by IBM which resulted in the quite successful Model 2250 graphic terminal. The DAC-1 software, from its inception, was three-dimensional oriented. GM did some significant work in creating and manipulating fairly complex surface geometry at a time when other graphics developers were focused on straight-forward two-dimensional orthographic drawings. In 1967, GM's president, Edward Cole, decided that the DAC-1 project had become too expensive and transferred future responsibility for this type of technology to the company's Manufacturing Development Staff.

Over the next several years, work on applying computer graphics to design problem continued at GM, although at a somewhat lower level of intensity. By 1970, an experimental design system utilizing an IBM System 360/67 with several 2250 III display terminals was in use.[53] GM subsequently developed advanced design software that eventually was called the Corporate Graphic System or CGS. It was used for automotive body design until well into the 1990s.

[53] Beckermeyer, Robert L. – *Interactive graphic consoles – Environment and software* - Proceedings of the Fall Joint Computer Conference, Houston, Texas 1970 Vol. 37 – AFIPS Press, pg. 315

# Chapter 4

# Research in the Mid to Late 1960s

While the early 1960s saw the first experimental CAD systems such as Sutherland's Sketchpad, Itek's Electronic Drafting Machine and General Motors DAC-1, the latter part of the decade saw a burst of research activity that laid the foundation for the eventual commercialization of this technology. Obviously, dedicated mainframe computers such as the TX-2 used by Sutherland would not be practical for commercial systems. Likewise, given the limited processing power of the then available computers, much of the graphics processing needed to be offloaded to the display terminals themselves as well as the memory for refreshing displayed images. This period of time saw the development of three important devices that eventually spurred the introduction of commercial CAD systems - the storage tube display, the minicomputer and the tablet.

**Development of the tablet as a light pen alternative**

As interest in computer graphics began to grow, so to did the interest in developing a low-cost graphical input device to replace the light pen. The latter device was somewhat expensive and required users to keep their hands raised while working. Although the light pen had the advantage of being able to directly select a displayed item, many researchers felt that it was an awkward way to work and began to look for an alternative technology, especially one that might be less expensive.

One of the first indirect pointing devices was the RAND tablet developed by Santa Monica, California-based RAND Corporation in 1964 working under a contract from the Department of Defense's Advanced Research Projects Agency in Washington. This device had an active surface 10.24 inches by 10.24 inches with a resolution of 100 lines per inch. The tablet was actually a large circuit board with X axis resolution lines in one direction and Y axis lines in the other. As the user mover a stylus across the surface of the tablet, the position in both X and Y directions was sensed and fed to the computer controlling the graphics display device.[1]

Initially, tablets provided a low cost alternative to the light pen, but, eventually, they proved to be invaluable when storage tube displays were introduced since a light pen could not be used with a storage tube display. At first, RAND simply provided copies of its tablet to other research organization but eventually it was commercialized by RAND and by other companies.

Additional development work was also underway at MIT's Lincoln Laboratory where Larry Roberts created an experimental pointing device that functioned in three-dimensional space using four ultrasonic sensors. While the technology was workable, the concept never really caught on with users and few three-dimensional pointing devices were manufactured.

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[1] Davis, M. R. and Ellis, T.O. – *The Rand Tablet: A Man-Machine Graphical Communication Device* - Proceedings of the Fall Joint Computer Conference, San Francisco, California 1964 Volume 26 Part 1– Spartan Books pg. 325

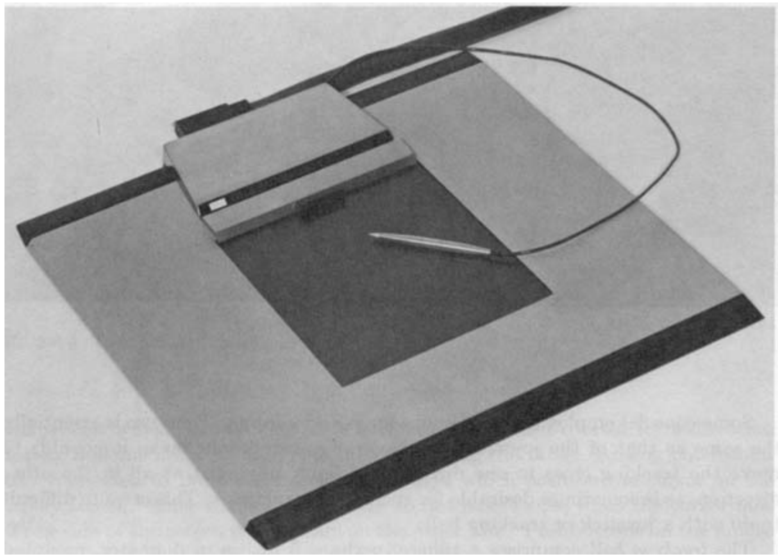

Figure 4.1
Rand Tablet[2]

Another device developed at Lincoln Lab around the same time was a hardware comparator that would take an X/Y coordinate location entered from a tablet device and determine the graphic element being pointed at without requiring the application program to examine the entire database looking for the displayed element nearest this location. It did this by recording the coordinate values of the location pointed at and then determining if any displayed vector or point went through that location. (I assume that it utilized a small area around the specific coordinate values in question) and when it found a match, caused a hardware interrupt so that the display item being pointed to could be identified.

According to Roberts, "With comparator hardware for the central display generator, position-pointing devices are preferable to light pens because there is no need to track them; the pointing is more precise, and they will work with long persistence phosphors."[3] With storage tube display terminals starting to become available around this time, the need for an alternative to the light pen was a major issue and the tablet appeared to provide that alternative. The need for a hardware comparator to identify displayed graphical elements faded as low cost computers with high computational capabilities became more prevalent. Consequently, hardware-based graphical comparators never became a key component of commercial CAD systems.

One problem associated with tablets was that they required a considerable amount of computer processing to track the stylus and convert hand movements to graphical input the host computer could understand. With the advent of time-sharing, host computers were being used simultaneously by multiple users and the resources were not available to support a significant number of graphic terminals equipped with tablets.

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[2] Prince, M. David – *Interactive Graphics for Computer-Aided Design* – Addison-Wesley Publishing Company, 1971, Pg. 58
[3] Roberts, Lawrence G. – *The Lincoln Wand* - Proceedings of the Fall Joint Computer Conference, San Francisco, California 1966 Volume 29 – Spartan Books pg. 223

 

System Development Corporation, a government contractor in Santa Monica, California, addressed this problem by placing a Digital PDP-1 between the graphic terminals and the host time-sharing computer. The PDP-1 took on the task of tracking stylus movement and providing data to the application program running on the host when the user initiated or completed a movement of the stylus such as defining the beginning or the end of a line. Pen movements were sampled by the PDP-1 250 or 500 times per second. At the higher rate, tablet support used about 30% of the PDP-1's computing capacity.[4]

While the Rand Tablet used a grid of fine lines (1,000 by 1,000 or about 100 per inch) through which signals flowed, other techniques were also promoted. Sylvania Electronic Systems introduced the Sylvania Data Tablet Model DT-1 which used an analog technique to determine the stylus position. The Sylvania unit could also provide a rough measure of height above the tablet as well as having several other interesting features such as being transparent so the tablet could be placed over a CRT screen. The DT-1 also used a pen for its stylus which enabled the user to create a hard copy of information being sketched. While these were all interesting features, users were either uninterested in them or were unwilling to spend the extra money for these capabilities and the device never caught on.[5]

Among the advantages the tablet had over the light pen was the fact the when the pen was held against the surface of the CRT, it physically blocked what the operator was pointing to. To get around this limitation many software programs used the concept of a "pseudo point" that was a displayed cursor offset slightly from the exact spot the operator was pointing to. Typically, the pseudo point would be slightly above the light pen's physical location. The application software would interpret the pseudo point as representing the coordinates the operator was actually interested in, whether it was to select an existing element or to define a new point on the screen.

### 1966 *Wall Street Journal* article

One of the major issues that has plagued the CAD industry during its entire history has been the lack of public recognition for what this technology can accomplish and the positive impact it has had on design and manufacturing productivity. One of the few early articles about CAD in the general press appeared in the October 25, 1966 issue of the *Wall Street Journal*. This front page article was titled "Engineers Focus Light On Screen to Design Visually Via Computer."

Written by Scott R. Schmendal, it started off: "Scientists and engineers who like to work out difficult problems by using sketches can dispense with such traditional tools as chalk and pencil. A major advance in computer technology is beginning to give them a major new tool – a TV-like screen linked to a computer, on which sketches can be made using beams of light."[6] Schmendal used automotive design analogies extensively in his article which was particularly well written given the overall newness of computer technology, much less interactive graphics. The article described how sketches of an

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[4] Gallenson, L – *A graphic tablet display console for use under time-sharing* - Proceedings of the 1967 Fall Joint Computer Conference, Anaheim, California 1967 Volume 31, Thompson Books, pg.689

[5] Teixeira, James F. and Sallen, Roy PG. – *The Sylvania data tablet: A new approach to graphic data input* - Proceedings of the 1968 Spring Joint Computer Conference, Atlantic City, N.J. 1968 Volume 32, Thompson Books, pg. 315

[6] Schmendal, Scott R. - *Engineers Focus Light On Screen to Design Visually via Computer* – Wall Street Journal, October 25, 1966

 

automobile could be created, edited, and rotated to different viewing orientations. This was done in a very straightforward manner.

A substantial portion of the article talked about the expected future ability of these graphics systems to create control tapes for NC machine tools. "…the day is fast approaching when the computer will be able, for example, to analyze a gear drawing on the screen and automatically turn out a coded tape that will describe how the part is to be manufactured."[7] At the time, part programming was still an extremely time-consuming process that was typically done manually. The author quoted S. H. (Chase) Chasen, who at the time was the head of computer graphics research at Lockheed-Georgia, describing the current state of NC development at that company.

Lockheed had generated experimental NC tapes the previous November and was planning to produce production parts for the C5A aircraft before the end of 1966. Chasen described the expected payoff for this application by comparing the new technology to that used with building the C141 plane where it took an average of 60 hours to prepare each control tape for the 1,500 parts produced using NC machine tools. Chasen was quoted as stating: "Our initial estimate was that computer graphics would reduce that average to about 10 hours but now we think that the savings may be even greater."[8] This work at Lockheed is described in greater depth below.

The article went on to list a number of companies doing research in applying computer graphics to engineering design including IBM, Control Data Corporation, Bunker-Ramo, General Electric, Sperry Rand, Information Displays and Scientific Data Systems. The article's description of graphics activity at GM was somewhat vague while its discussion of IBM's work in this area was more descriptive. IBM had introduced the 2250 graphics terminal as a System/360 peripheral device in April, 1964. By the date of the *Wall Street Journal* article, the company had delivers "dozens" of units and had orders from "hundreds" of customers for more units, about equally split between industrial and defense-aerospace users.[9] It is entirely possible that IBM meant to say that it had orders for hundreds of additional units rather than hundreds of customers. IBM was also reported to have introduced an improved version of the 2250 priced at $76,800 each.

Schmendal credits Ivan Sutherland, with creating much of the interest in computer graphics as an engineering design tool. After completing his work on Sketchpad and obtaining his Ph.D. in electrical engineering in 1963 , Sutherland had taken a job with the Department of Defense Advanced Research Projects Agency as director of information processing techniques which was followed in 1966 with a stint as a professor at Harvard University. The final section of the article predicted that time-sharing would have a major impact on reducing the costs of using computer graphics.

One of the more interesting aspects of this article is that Schmendal quotes a graphics survey done by Adams Associates based in Cambridge, Massachusetts which stated: "A substantial increase in the use of CRT (cathode-ray tube) display devices is now in the making." This survey may well have been a precursor of the periodic report the company later published called the *Computer Display Review* of which I had a major hand in initially producing and personally wrote the section on display technology.

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[7] Ibid.
[8] Ibid.
[9] Ibid.

**Computer graphics developments**

The latter half of the 1960s saw significant progress in the development of computer graphics devices, both line drawing refresh displays and storage tube displays. Point display refresh devices were still being used because of their relatively lower cost but they were starting to slip out of favor for the most part in that they simply did not result in the quality images required for engineering design work or similar applications. Storage tube displays are discussed later in this chapter.

One of the major issue involving refresh display devices was that the image on the CRT screen had to be redrawn or refreshed 30 or more times per second in order to avoid having the image flicker. Initially this was accomplished by having the host computer feed the data to the display device vector by vector. In some cases this was done by continually regenerating vector information from a data file describing the data. The computer would determine how much of the image was to be displayed and clip any vectors that fell outside the viewing area. This type of operation ate up a considerable portion of the host computer's computational capacity.

One way around the problem and in order to enable the host computer to support multiple display devices simultaneously was to offload as much of this work as possible from the computer to the terminal. The technique used was to equip the display terminal with its own memory and a computer-like processor that would store the data to be displayed and continually regenerate the image on the CRT. Called a "display list," the idea to do this had been around for several years and was not particularly novel.

The display processor continually regenerated the displayed image from the data stored in the display list without placing any computational requirement on the host computer. What was imaginative was to provide these display processors with a subroutine capability. Multiple copies of a symbol could be displayed even though the display list contained just a single copy of the graphical elements defining the symbol. The display processor would treat that single copy as a subroutine much like a programmer would in a host computer program.

Academic research centers, commercial companies and government laboratories were all working on developing display list processors. One early such project underway at the National Bureau of Standards was described in an article by D. E. Rippy and D. E. Humphries: "MAGIC – A Machine for Automatic Graphics Interface to a Computer" which appeared in the "Proceedings of the 1965 Fall Joint Computer Conference."[10] The key issue in the development of devices such as MAGIC was to establish the proper balance between hardware and software functions.

Gradually, display devices took on more and more of the tasks required to generate displayed images. This included adding capabilities such as clipping the portion of images that fell outside the CRT screen, circle and arc generators and character generators. Rather than have software on the host computer define the individual elements of different line styles (short dashes, long dashes, dim, bright, etc.) each element in the display list could be coded for line type and the display processor would create the image accordingly.

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[10] Rippy, D. E. and Humphries, and D. E. - *MAGIC – A Machine for Automatic Graphics Interface to a Computer* – Proceedings of the 1965 Fall Joint Computer Conference, Las Vegas, Nevada 1965 Volume 27 Part 1, Spartan Books, pg. 819

 

Another group working on developing a graphic terminal that would place a nominal computing load on a host computer was Bell Telephone Laboratories in Murray Hill, New Jersey. Called GRAPHIC 1, the system they put together in 1965 consisted of a Digital PDP-5 minicomputer and a Digital Type 340 Precision Incremental Display as shown in Figure 4.2. The PDP-5 was a 12-bit machine with a 4,096-word memory and 18 microsecond add time but no hardware multiply/divide capability. It did have very flexible input/output features. The 340 used an incremental point display method which significantly limited the complexity of an image.

According to William Ninke, about 200 inches of line drawing or 1,000 characters could be displayed flicker free at 30 frames per second. Once an image was communicated to the GRAPHIC 1, it was stored in the PDP-5's memory and the image continued to be refreshed without any further action on the part of the host computer. A variety of input devices were attached to this research system including a light pen, keyboards, toggle switches, potentiometers and a two-dimensional track ball. Access to an application program on the larger machine was required in order to make changes to the displayed image. At Bell Lab the host computer was a batch-oriented IBM 7094 that provided access to the Graphic 1 at intervals ranging from every two to six minutes. This was not conducive to real-time applications and it demonstrated the need for commercial mainframe systems that could operate in a more interactive time-sharing mode.[11]

Figure 4.2
Bell Laboratories GRAPHIC 1 Console[12]

One subject the researchers at Bell Labs focused on was the relative benefits of using a light pen versus the recently developed Rand tablet. The primary tradeoff was the light pen's ability to identify displayed objects given appropriate interface hardware and

[11] Ninke, William H. – *GRAPHIC 1 – A Remote Graphical Display Console*, Proceedings of the 1965 Fall Joint Computer Conference, Las Vegas, Nevada 1965 Volume 27 Part 1, Spartan Books, pg. 839
[12] Ibid, pg. 840

 

software as compared to the need to search the graphic database to find the item being indirectly pointed to with the tablet.

Ninke stated that they found the light pen to be preferred over the tablet. There may have been two characteristics of the GRAPHIC 1 system that led to this conclusion. First, the PDP-5 was not a particularly fast computer and without a hardware multiply and divide capability it would have been time-consuming to find the item the user was pointing to with the tablet stylus. Second, the amount of information that could be displayed on the GRAPHIC 1 screen was quite limited, making it easier for a light pen to distinguish between displayed elements. If a faster computer and/or a display with greater image capacity were used as part of the console configuration, the relative merits of the two devices might have been perceived differently.

Within two years, Bell Laboratories made substantial progress in developing interactive graphics tools. The IBM 7094 was replaced by a GE 645 mainframe computer that was specifically designed to support time-sharing software and multiple remote devices. The 645 had a memory of 256K 36-bit words and was approximately twice the speed of the 7094. Two types of graphics terminals were attached to the 645. One set, called the GLANCE system, provided view only graphics to time-sharing users whose primary device for data entry was a teletype terminal. Of more interest to our story was a new interactive terminal called the GRAPHIC 2. The PDP-5 used with the GRAPHIC 1 was replaced by a Digital PDP-9, a machine that was nearly an order of magnitude faster while substantially less expensive. The same basic architecture was used, however. Graphic files were downloaded from the host 645 computer over a 201 Dataphone modem at 2,000 bits per second, stored in the PDP-9 core memory and then used to refresh the CRT display. Interaction continued to use a light pen.

According to a paper presented at the 1967 Fall Joint Computer Conference by Carl Christensen and Elliott Pinson, response time for the new equipment was measured in seconds as compared to minutes for the GRAPHIC 1. For the most part, the software developed by Bell Laboratories during this time period provided basic data management and graphical services but did not go as far as complete applications that could be used for interactive engineering design.[13]

Other research groups looked for ways to reduce the amount of data that had to be transmitted to a remote graphics terminal being used in a time-sharing environment. Since communication lines in the mid-1960s typically operated at speeds as low as 300 bits per second, it could take an painfully long time to sent an image to the remote terminal if had to be done point-by-point or as a series of short vectors. This was becoming an increasingly serious problem as graphic applications were beginning to deal more frequently with curved lines as well as with storage tube displays which required that the entire image be redrawn whenever a graphical item was moved or deleted. MIT's Project MAC developed a prototype system that reduced the amount of data needed to transmit curvilinear entities to only a few characters per line.[14]

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[13] Christensen, Carl and Pinson, Elliott N. – *Multi-function graphics for a large computer system* – Proceedings of the 1967 Fall Joint Computer Conference, Anaheim, California 1967 Volume 31, Thompson Books, pg. 697

[14] Dertouzos, M.L. and Graham, H.L. – *A Parametric Graphical Display Technique for On-Line Use* – Proceedings of the 1966 Fall Joint Computer Conference, San Francisco, California 1966 Volume 29, Spartan Books, pg. 201

 

Development work on stand-alone and remote graphic terminals was also underway at IBM's facility in Kingston, New York. The company interfaced one of its 2250 Model 4 displays to an IBM 1130 computer. The 2250 had originally been introduced as an IBM System/360 peripheral and was only used with other computers on an infrequent basis. The 1130 had superceded the IBM 1620 in 1965 and was a popular machine for engineering applications. It was not particularly fast by the standards of the late 1960s with an add time of just eight microseconds. A Digital PDP-9 which sold in the same price range was nearly four times faster.

IBM personnel made several modifications to the 1130 to support the 2250 display and created software to support interactive operations. One key characteristic of this system was that the actual 2250 display commands were stored in the 1130 core memory and fed out to the display using a cycle stealing method. In effect, when the display needed the next command, its request to the computer for that data took precedence over all other computer operations, but it did so in a totally transparent method. At 40 frames per second, this system could display the equivalent of about 2,100 inches of line drawing on the unit's 21-inch display.

It appears that the primary intent of the 1130-based system was to act as a graphic interface for engineering programs being run on an IBM System/360 host. The unit was able to communicate with a host computer at speeds ranging from about 150 characters per second up to 30,000 characters per second. The latter was a very high data transfer rate for that era and probably would not have been economically viable for most engineering design organizations. There is no record that I have been able to find that indicates IBM ever developed commercial CAD software for the combination of the 1130 and 2250 nor does it appear that the company actively sold this type of configuration for others to develop that type of software.[15]

**The growth of commercial display terminals**

A number of companies were started during the 1960s to produce commercial refresh-type computer graphic terminals including Information Display Incorporated, Adage, Evans & Sutherland and Imlac. In addition, several of the computer manufacturers also entered this market including IBM, Control Data Corporation and Digital Equipment Corporation. Many of these display products required a computer system to provide the memory for refreshing screen images while others included the refresh memory in the display controller. Some had line, circle and character generators built into the base product while others sold these modules as options.

Computer display terminals of the late 1960s were not cheap. A typical system interfaced to a minicomputer sold for $45,000 to $120,000. A major element of the cost was in the graphics controller, rather than in the CRT display itself. As a consequence, most vendors came up with configurations that allowed users to attach multiple displays to a single controller which in turn was interfaced to a computer system. Some products, such as CDC's Digigraphic units and IBM's 2250, only interfaced to those companies own computers while the non-computer vendors stressed the ability of their units to interface to a wide range of different computers.

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[15] Rapkin, Michael D. and Abu-Gheida, Othman M. – *Stand alone/ remote graphic system* – Proceedings of the 1968 Spring Joint Computer Conference, Boston Massachusetts 1968 Volume 33 Part One, Thompson, pg.731

Perhaps the highest performance graphics terminals available by late 1968 were the AGT units being sold by Boston-based Adage. In a paper presented at the 1968 Fall Joint Computer Conference, Adage personnel pointed out that to dynamically scale and rotate graphical data in three-dimensional space would require the execution of one million instructions per second for an image containing 1,000 vectors and a refresh rate of 40 frames per second. Many of these instructions would be time-consuming multiply operations. While large host computers were capable of this level of performance, tying up such a machine to support interactive graphics was not economically feasible.

The Adage terminals not only incorporated a 30-bit minicomputer but also utilized a custom-designed display processor that was capable of translating and rotating up to 5,000 vectors at 40 frames per second. This device executed 16 specialized multiply operations and 12 adds in less than four microseconds. The company's AGT10 was designed to support two-dimensional operations while the AGT30 and the AGT50 targeted three-dimensional applications. While the results were spectacular to view, the equipment was far too expensive to be practical for large volume CAD operations. Most of the units the company built were used in specialized applications. It was not until Adage began to build less expensive terminals that were plug compatible with IBM 2250-type displays that the company generated reasonably decent revenue.[16]

**The emergence of low-cost terminals**

While vector refresh terminal technology was evolving at a rapid rate during this period, the cost of a typical unit was excessive for most applications. Although several commercial CAD systems, including CADAM and CATIA, would continue to use vector refresh terminals until the mid-1980s when IBM introduced the 5080 raster display, a lower cost alternative was obviously needed. The answer in the late 1960s was the storage tube display.

Storage tube CRTs had been around for several decades. Originally developed as the display component for oscilloscopes, they were also used as memory storage devices in early computers such as MIT's Whirlwind I. As an interactive display device, they had a significant cost advantage over refresh displays but suffered from the fact that when any changes were made to the image being displayed, the entire screen had to be erased which took a large fraction of a second and then the entire image had to be regenerated. The latter step could take several minutes for a moderately complex image, especially if a serial interface was being used. While other companies built storage tubes, Tektronix was by far the leading producer since that company was also the world's leading manufacturer of oscilloscopes. The company was rather slow, however, in appreciating the applicability of the storage tube as a low-cost display terminal.

Early developments involving the use of storage tube displays took place at MIT's Project MAC. This led to the establishment of three commercial companies in the Cambridge area, Computer Displays, Computek and Congraphic. Computer Displays was founded by Rob Stotz and Tom Cheek and several other researchers from MIT's

[16] Hagen, Thomas, G., Nixon, Richard J. and Schaefer, Luis J. - *The Adage graphics terminal* – Proceedings of the 1968 Spring Joint Computer Conference, Boston Massachusetts 1968 Volume 33 Part One, Thompson, pg.747

 

Electronic Systems Laboratory. The company's first product was called the ARDS (Advanced Remote Display Station) terminal.

Figure 4.3
Computek Series 400 Display System[17]

Computek was founded by Michael Dertouzos who went on to become the long time director of MIT's Laboratory for Computer Sciences until his death in 2001. The Computek Series 400 machines used an 11-inch diameter storage tube display and ranged in price from $6,700 to $11,200. Tablet input added $3,700 to $5,600 to the price tag. These units incorporated both curve and symbol generation capabilities as well as line generation with 1024 by 800 screen resolution.

Conographic was founded by Luis Villalobos who subsequently became a venture capitalist in California. The Conograph/10 provided a limited refresh capability in addition to the stored image. Up to 50 inches of line could be displayed in this refresh mode, a capability which significantly improved user interaction. This was a fairly sophisticated unit with 2048 by 1520 viewable resolution, a circle generator and a very advanced curve generator that required perhaps a tenth of the data to display a curve that other system required. A fully configured unit sold for around $17,000. While higher priced than the Computek Series 400, the additional functionality and resolution probably justified the extra cost.

Eventually, Tektronix realized that there was money to be made selling terminals in addition to simply selling storage tube modules on an OEM basis. The company's first terminal product was the Model T4002 which was a fairly basic device with 1024 by 1024 resolution on an 11-inch diagonal screen. Although the unit included line and character generators, it did not include a circle, curve or symbol generator. A typical unit sold for about $10,000. Tektronix had a much larger sales organization than Computer

[17] Computer Display Review, GML Corporation, 1976.

 

Displays, Computek or Conographic and fairly quickly became the dominating vendor in the low-cost storage tube terminal market. At the same time, it continued to sell storage tube displays on an OEM basis to any company that wanted to build its own terminals.

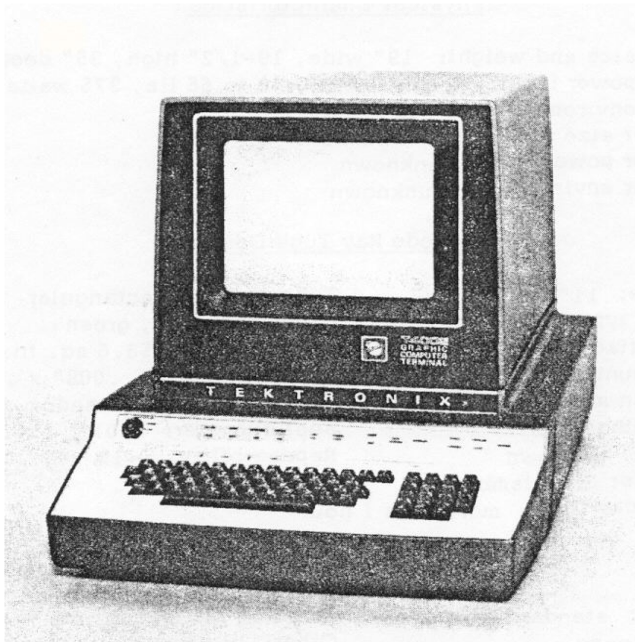


Figure 4.4
Tektronix T4002 display

Along with the T4002, Tektronix also introduced the 4601 Hardcopy Unit. This device copied whatever was displayed on the terminal's screen without necessitating any computer processing of the data. As a consequence it was far faster than a plotter but the image size was just 8 ½ by 11-inches. The paper had a silver emulsion on it that faded over time but these copiers were a fast way to get a quick copy of whatever you were working on. Over the years, Tektronix would sell a huge number of screen copiers and a tremendous volume of the paper they used. It was much like Hewlett-Packard's current market position with inkjet cartridges.

**The minicomputer becomes a key technology building block**

Most of the early graphics research was done on large mainframe computers such as the TX-2 at Lincoln Laboratory or the big IBM System/360 machines used at General Motors and Lockheed. While a reasonably economic system could be configured if one of these machines could handled a moderate number of terminals, they were not amenable to fostering a commercial CAD industry. Basic mathematical instruction speeds were too slow to support more than a few terminals and the initial cost of a system was far too high.

One exception was the Electronic Drafting Machine developed at Itek and which later formed the basis of Control Data's Digigraphics system. As described in Chapter 6, a Digital Equipment Corporation PDP-1 was initially utilized. One problem with early minicomputers was that comprehensive real-time operating systems were not available and application programmers were required to provide many of the basic capabilities that we take for granted today.

By 1964, several companies besides Digital including Scientific Data System and Computer Control, were selling relatively low cost computer that were applicable to interactive graphics applications. Over the next five years, this portion of the computer industry underwent significant growth and the number of 16 to 24-bit machines that could support interactive graphic applications expanded rapidly. New vendors for this type of machine included Computer Automation, Control Data, Hewlett-Packard, Honeywell which had acquired Computer Control, IBM, Interdata and Systems Engineering Laboratory. On the other hand, many of the larger computer manufacturers such as General Electric, Burroughs and Univac basically ignored this emerging market.

One of the most significant product introductions was Data General's launch of the 16-bit Nova in January 1969. Ed deCastro, the founder of Data General, previously worked at Digital as a senior hardware design engineer and was involved in designing a new 16-bit minicomputer called the PDP-X. When Digital decided to pass on deCastro's design in lieu of another plan for what eventually became the PDP-11, he left and started his own company to build his version of the PDP-X. The Nova was the company's first product. This machine was aggressively priced and was well tuned for interactive applications. The early versions were not particularly fast, however, with an add time of 5.9 microseconds, the equivalent of less than 0.2 MIPS.

The Digital PDP-11 was the minicomputer along with the Nova that really energized the early CAD industry. First shipped in early 1970, it was also a 16-bit machine. A basic system with a 4K (words not bytes) memory sold for $13,900. Additional memory was $4,500 per 4K words or the equivalent of $562,500 per megabyte. (Thirty-five years later memory sells for less than $0.10 per megabyte.) Digital would continue making this machine in one form of another until well into the 1990s. The initial operating systems for both machines were fairly basic and early CAD software developers were forced to provide most of this functionality themselves. The combination of a low cost minicomputer with 8K of memory, an 11-inch storage tube display and a tablet resulted in an economical hardware configuration for emerging CAD system vendors.

**Spreading the word**

In 1965, Adams Associates, a consulting firm in Bedford, Massachusetts, began publishing a compendium of commercially available graphics terminals called the *Computer Display Review*. One of the significant characteristics of this publication was that the authors defined three test cases – a schematic diagram, an architectural floor plan and a weather map – and used these test cases to determine the time it would take to display each image based upon the manufacturers' specifications.

An overview of then current graphics technology written by Carl Machover was published in the proceedings of the 1967 Fall Joint Computer Conference held in Anaheim, California. Machover, who is one the graphics industry's most respected consultants, was the vice-president of Information Display Incorporated at the time. While the paper did not provide extensive details about the different commercially available products being marketed at the time, it did contain an interesting list of 16 companies manufacturing display hardware. Except for Bolt, Beranek & Newman (now called BBN Technologies), IBM, and International Telephone & Telegraph (now called ITT Industries), none of these companies are still in business and only IBM is currently manufacturing computer products used for CAD applications.

The others, including Bunker-Ramo, Information Displays, Philco-Ford, and Scientific Data Systems, are all long gone, having been merged into other companies or simply closed down. All the systems sold by these manufacturers were random positioning refresh displays except for BBN which was one of the first to offer a storage tube device and Philco-Ford which had one of the first raster displays.

There are several significant aspects to Machover's paper.

- The first was a discussion about the differences between electrostatic and magnetically deflected CRTs. The trend by 1967 was to use either a combination of the two types of deflection or a dual magnetic deflection setup that utilized a lower inductance coil and a higher inductance coil.
- The paper covered in depth what was meant by "flicker free" and generally concluded that for most phosphors this required a refresh rate of about 40 frames per second. An interesting aspect of this position is that most manufacturers claimed that 30 frames per second was sufficient. My personal experience was that at 30 frames per second the flicker was generally intolerable.
- Machover explained how most commercial units contained a display generator that could produce points, lines, alphanumeric characters and circles from a basic display list stored in either the computer's memory or a memory contained within the display device itself. Most systems contained information in the display list that defined character size, vertical or horizontal orientation, line brightness, and line type such as solid, dots, dashes or dot/dash. He mentioned that the emergence of low-cost minicomputers would lead to the display systems incorporating these computers.
- Perhaps the most useful part of the paper was a discussion concerning the volume of data that could be displayed, considering the minimum acceptable frame rate. This was determined by the time it took for the display beam to move to a new position, the time to draw a vector and how well the data was organized so that beam movement between vectors and/or characters was minimized.[18]

**Image processing and surface geometry**

At this early stage of graphics technology development, most developers were still struggling with being able to effectively work with two-dimensional line drawings. A number of interesting projects were underway at academic institutions such as MIT, Syracuse University and the University of Utah in creating three-dimensional models involving complex surfaces and in generating shaded images of these models. Research was also underway defining efficient methods for creating displays with hidden lines removed.

[18] Machover, Carl – *Graphic CRT terminals – characteristics of commercially available equipment* - Proceedings of the 1967 Fall Joint Computer Conference, Anaheim, California 1967 Volume 31, Thompson Books, pg. 149

 

Some of the more interesting work was being done at the University of Utah where David Evans was developing techniques for creating shaded images on monochromatic displays.[19] The others working on this project were Chris Wylie, Gordon Romney and Alan Erdahl. Whether or not they were the first to use the technique, they became strong proponents of dividing surfaces into small triangles. “Any developable surface can be approximated arbitrarily accurately with small, but finite, triangles.”[20]

I remember visiting Evans around this time and being impressed by the work they were doing at Utah. The software was written in FORTRAN IV and called PIXURE. Both a cube made up of 12 triangles and a tetrahedron made up of four triangles took about 25 seconds to process on a UNIVAC 1108 at 512 by 512 resolution. Although this was a large mainframe by 1967 standards, it only had about 1.3 MIPS of processing power. PIXURE required about 14K words (36-bit ) for storing a picture with 100 triangles. This was a serious limitation since the maximum memory for a UNIVAC 1108 was just 256K words and the typical machine had much less.

One of the objectives of the research team was to develop algorithms whose processing time expanded linearly with the target resolution of the image being generated and with the number of triangles in the image. A problem with far too many researchers is that they get mentally locked in to the performance restrictions of the computer hardware currently being used. The Utah group had the ability to see that future computers would provide far greater performance. According to the Utah team: “The parallel and incremental characteristics of the algorithm lead us to believe that real-time movement and display of half-tone images is very near realization.”[21]

An additional point was that the effectiveness of the algorithms they had developed depended to a great extent on the ability of software to convert arbitrary surfaces into a suitable mesh of triangles. Figure 4.5 shows a convex tetrahedron displayed at 512 by 512 resolution.

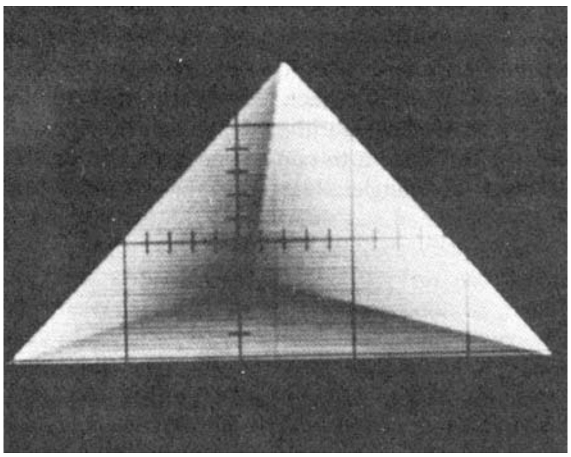

Figure 4.5
Image of Convex Tetrahedron Created with University of Utah PIXURE Software

[19] Wylie, Chris et al – *Half-tone perspective drawings by computer* - Proceedings of the 1967 Fall Joint Computer Conference Anaheim, California 1967 Volume 31, Thompson Books, pg. 49
[20] Ibid.
[21] Ibid, pg. 58

 

About the same time that early visualization work was underway at the University of Utah, Arthur Appel was tackling similar problems at the IBM Research Center in Yorktown Heights, N.Y. He experimented with using ray tracing techniques to create shaded images. Since color displays were still off in the future and contemporary refresh displays had limited ability to vary spot intensity, Appel utilized a technique called "chiaroscuro" with which artists and illustrators used light and shade to achieve a three-dimensional effect.

The work done at Utah required that the source of illumination be at the viewpoint and since it was a single point light source, no shadows could be generated. Appel's ray tracing techniques allowed the light source to be placed in an arbitrary location enabling the software to create shadows. The images his software generated consisted of multiple plus signs. Shading was accomplished by varying the size of the plus signs as well as their spacing. Generating a shaded image of a rather simple part took about 30 minutes on an IBM 7094 computer. The images were then plotted on a CalComp plotter. While this was not a practical graphics application, it did lay the foundation for more effective approaches that would follow. See Figure 4.6 for an example of Appel's work.

In a paper presented at the 1968 Spring Joint Computer Conference Appel made a very prescient comment. "If techniques for the automatic determination of chiaroscuro with good resolution should prove to be competitive with line drawings, and this is a possibility, machine generated photographs might replace line drawings as the principal

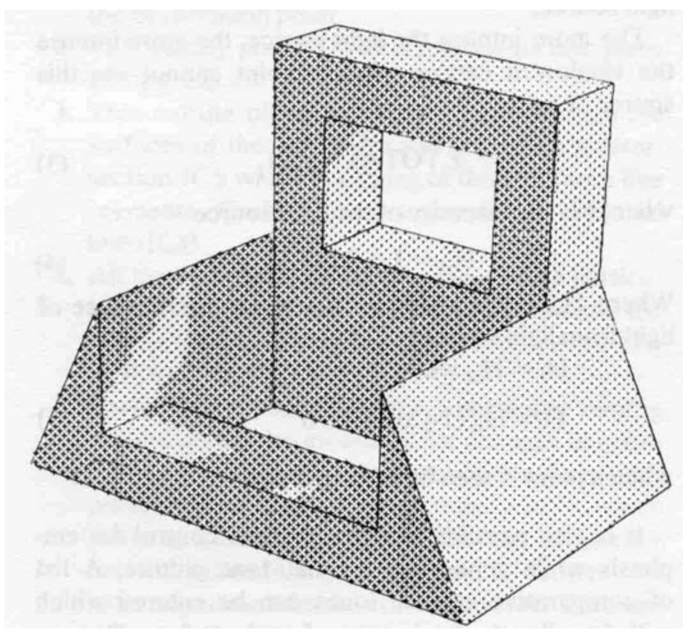

Figure 4.6
Shaded Image Using Ray Tracing Technique With Light Source Behind Object[22]

[22] Appel, Arthur – *Some techniques for shading machine renderings of solids* - Proceedings of the 1968 Spring Joint Computer Conference, Atlantic City, N.J. 1968 Volume 32, Thompson Books, pg. 44

 

mode of graphical communication in engineering and architecture."[23] It might have taken over 30 years for this to have occurred, but in many cases today, color shaded images of mechanical products, buildings and process plants are used as the primary means of exchanging design information between relevant parties.

**Data management and application programming developments**

As graphics hardware and computer technology began to mature in the mid-1960s it became increasingly obvious that new techniques had to be developed for storing and manipulating engineering design data. As described in the prior chapter, Doug Ross had made an important contribution with his "plex" architecture concept. A number of researchers associated with both academic institutions and commercial companies went to work on defining extensions to Ross' original concept in attempts to make the development of interactive systems more efficient. For the most part, this work was constrained by contemporary hardware and communications equipment. One of the most significant limitations was the small amount computer memory installed in most computers due to cost considerations. Remote communications had an upper limit of about 2,400 bits per second.

Ivan Sutherland's initial graphics work at Lincoln Laboratory soon led to a much broader series of research projects, attracting some of the best talent associated with the development of computer graphics. Larry Roberts wrote several technical papers that helped define the theoretical foundation for managing display files and the matrix mathematics that formed the basis for much future work.[24] He worked with William R. (Bert) Sutherland, Ivan's older brother, in 1964 to develop programming tools that would facilitate the implementation of graphic applications on Lincoln Laboratory's TX-2 computer. CORAL (Class Oriented Ring Associative Language) was a service system consisting of a basic data structure, a collection of subroutines that would manipulate this data structure and a macro language for defining the data structure and the operations to be performed on it.[25]

Andries Van Dam and David Evans, while working at Brown University and the University of Pennsylvania respectively, developed a compact data architecture called PENCIL (Pictorial ENCodIng Language) that minimized the extent with which pointers were used. PENCIL supported the easy addition and deletion of sub-pictures, no entity identification number was required for browsing through a file and the overhead per sub-picture was low. The key aspect of their work was that it served as a foundation for other research in graphical data management.[26]

Around 1967, Harvard University joined the growing number of academic institutions working on interactive graphics technology. One of the first people to join its staff in this area was William Newman who had earned his Ph.D. at the University of

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[23] Appel, Arthur – *Some techniques for shading machine renderings of solids* - Proceedings of the 1968 Spring Joint Computer Conference, Atlantic City, N.J. 1968 Volume 32, Thompson Books, pg. 37

[24] Roberts, Lawrence G. – *Homogeneous Matrix Representation and Manipulation of N-Dimensional Constructs* – Adams Associates Computer Display Review, May 1965

[25] Roberts, Lawrence G. – *Graphical Communications and Control Languages* – Information Systems Sciences, Proceedings of Second Congress, Spartan, 1965

[26] Van Dam, Andries and Evans, David – *A compact data structure for storing, retrieving and manipulating line drawings*- Proceedings of the 1967 Spring Joint Computer Conference, Atlantic City, New Jersey 1967 Volume 30, Thompson Books, pg. 601

London and come to the United States a year or so earlier and initially worked at Adams Associates in Bedford, Massachusetts. Newman would go on to write one of the most widely read books on the subject of computer graphics with Robert Sproull, "Principals of Interactive Computer Graphics."[27]

In a paper presented at the 1968 Spring Joint Computer Conference in Atlantic City, New Jersey, Newman described some of the work then underway at Harvard in developing problem-oriented programming languages for graphic applications. The basic principal was fairly straightforward – for every action taken by a user, there was a specific reaction executed by the computer depending upon the current state of the program. Newman felt that any language used to develop graphic programs needed to be as simple as possible if it were to be used by a wide range of programmers. The software developed at Harvard, the Reaction Handler, met these criteria. In his paper, Newman contrasted the Reaction Handler to the ICES System developed by Dan Roos at MIT which he felt was not applicable to interactive tasks and the AED System being developed by Doug Ross at MIT's Project MAC.[28] The latter was a very generalized language which had attractive features but probably was overly sophisticated for commercial applications.[29]

Perhaps the most comprehensive paper describing the requirements for a graphics system that was published during this period appeared in the proceedings of the 1968 Fall Joint Computer Conference. Written by Ira Cotton of Sperry Rand Corporation and Frank Greatorex of Adams Associates, it described a system capable of supporting remote graphics terminals being implemented on a UNIVAC 1108 computer. The graphics stations consisted of UNIVAC 1557 Display Controllers and UNIVAC 1558 Display Consoles. The authors defined their basic objective of providing the fastest possible response for console operators while at the same time minimizing the load placed on the host computer.[30]

Cotton and Greatorex's work required a careful analysis of which functions should be handled by the remote consoles and which should be handled by the host computer. The database they proposed extensively utilized ring chaining as developed by Bert Sutherland at Lincoln Laboratory. There was also significant emphasis on making the system as hardware independent as possible. If the details of the remote consoles changed, that was not supposed to affect the host software. This was a laudable goal that many organizations would attempt to meet in subsequent years but few would accomplish until the personal computer and Windows became industry standards in the 1990s.

Like other systems being developed at that time, they had to contend with communications links that had a maximum speed of 2,400 bits per second. As a consequence, data transferred from the host to the remote consoles were compressed to

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[27] Newman, William M. and Sproull, Robert F. – *Principals of Interactive Computer Graphics,* McGraw Hill, New York, 1973

[28] Ross left MIT in 1969 and founded SofTech, a computer software firm. Although SofTech was not involved in computer graphics during its early years, today it is actively involved in the CAD industry after acquiring Workgroup Technology, a PDM developer, and CADRA from MatrixOne.

[29] Newman, William M. – *A system for interactive graphical programming* – Proceedings of the 1968 Spring Joint Computer Conference, Atlantic City, N.J. 1968 Volume 32, Thompson Books, pg. 47

[30] Cotton, Ira W. and Greatorex, Frank S. Jr. – *Data structures and techniques for remote computer graphics* – Proceedings of the 1968 Fall Joint Computer Conference, San Francisco, California. 1968 Volume 33, Thompson Books, pg. 533

 

the maximum extent possible. Data describing conic entities were transferred in a parametric format and then expanded at the remote terminal into actual displayable elements. The team working on this project included R. Ladson, N. Fritchie and G. Halliday of UNIVAC and Dan Cohen and Roger Baust of Adams Associates. Much of the research work going on a Lincoln Laboratory at the time was being done under contract by Adams Associate personnel.

**Displaying complex images**

As noted in several places in this narrative, the computer systems available during the mid to late-1960s were either relatively expensive or if more affordable, had limited computational performance. According to the October 1966 issue of the Adams Associates *Computer Characteristics Quarterly*, the rental cost for an IBM 360 Model 65 or Model 67 computer started at $34,000 per month and could go up to $100,000 per month. This was for a machine with an add time of 1.3 microseconds and a maximum internal memory of 1MB. Lower cost minicomputers that could support interactive graphics were starting to become available but a Scientific Data Systems 930 which leased for $2,650 per month had an add time of 3.5 microseconds and a maximum memory of 32K 24-bit words.[31]

Generating complex curves on a display terminal required either a considerable number of instruction executions if it were to be done each time an image was refreshed or a considerable amount of memory to store a large number of short vectors if it were to be done once and the data saved in memory. Therefore, a number of researchers explored different means to display these curves more efficiently. A substantial amount of work was done throughout the 1960s at Lincoln Laboratory by Tim Johnson, Larry Roberts, John Ward, Charles Seitz and Howard Blatt including the building of experimental hardware for generating conic curves independent of the host computer.[32]

During the late 1960s Harvard University also became a hotbed of graphics research with people such as Ivan Sutherland, Robert Sproull, Dan Cohen, Ted Lee and Robin Forrest leading some of the more significant work. One project Sutherland and Sproull collaborated on was the implementation of a fast method for displaying portions of two and three-dimensional images on a CRT screen. Usually referred to as widowing, it is a computational intensive task when done using brute force methods. Sutherland and Sproull, working with Cohen and Lee, both of whom were Ph.D. candidates at Harvard, came up with a technique for finding elements falling within a window by calculating successive midpoints of a line. This method was computationally far less extensive than prior techniques.

Called a clipping divider, the algorithm they defined was subsequently implemented in hardware. This was an independent device that logically sat between the computer and the display terminal. The computer would feed it raw graphic elements and the clipping divider would determine what portion, if any, of the element fit within the display window, would calculate its translated coordinate values and then send those values to the display terminals where it would be stored in the units display memory.

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[31] Adams Associates – *Computer Characteristics Quarterly* – October 1966

[32] Blatt, Howard – *Conic display generator using multiplying digital-analog decoders* - Proceedings of the 1967 Fall Joint Computer Conference, Anaheim, California 1967 Volume 31, Thompson Books, pg. 177

The Harvard team built a matrix multiplier unit to facilitate the three-dimensional transformations needed for the translation of curved geometry. They were also exploring combining new hidden line removal algorithms developed at the University of Utah by John Warnock (who would go on to form Adobe Systems a few years later) with the clipping divider but it appears that this was never completed, at least not at Harvard. Before 1968 was over, Sutherland moved on to the University of Utah and Sproull to Stanford University.[33] A few years later Sutherland was one of the founders along with David Evans of Evans & Sutherland in Salt Lake City. That company used a version of the clipping divider in its early graphic systems.

There were a number of other very bright people working at this time on applying advanced mathematical techniques to the display of complex geometric curves and surfaces. Possibly one of the brightest was Cohen who moved to Harvard University after working at Adams Associates. While at Adams Associates, Cohen worked with Frank Greatorex to program a Systems Engineering Laboratory minicomputer to simulate aircraft flight operations. I do not know if this was the first graphics flight simulator, but it was definitely one of the early such programs. SEL had hired Adams Associates to program this application so it could be used to demonstrate their hardware at trade shows. It was first used at the 1967 Spring Joint Computer Conference and was one of the hits of the show.[34]

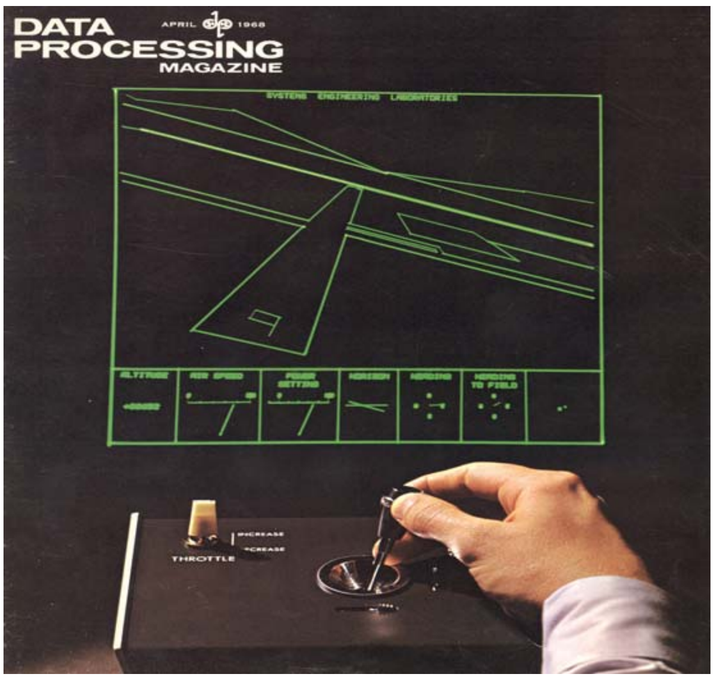


Figure 4.7
SEL Flight Simulator on Cover of *Data Processing Magazine*[35]

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[33] Sproull, Robert F. and Sutherland, Ivan – *A clipping divider*- Proceedings of the 1968 Spring Joint Computer Conference, Boston Massachusetts 1968 Volume 33 Part One, Thompson, pg. 765

[34] Greatorex, Frank S. Jr. and Cohen, Dan – *Producing Dynamic Perspective Views for Vehicle Simulation* – Data Processing Magazine, April 1968

[35] Ibid.

 

At Harvard's Aiken Computation Laboratory, Cohen and Lee teamed up to explore mathematical procedures for displaying generalized curves. The work they did is far too sophisticated for a detailed description to be included in this book but suffice it to say that they pushed forward the state of the underlying principals guiding future graphics technology developments.[36]

**In-House CAD developments gain momentum**

The major difference between research laboratory developments, whether done in an academic or industrial environment, and development done in a commercial environment is that the latter activity is expected to produce usable results within a reasonable period of time. A good example is the work done in the mid-1960s at Lockheed-Georgia Company. This work was briefly covered in the *Wall Street Journal* article mentioned earlier. A more comprehensive description of the effort underway in the mid to late 1960s at Lockheed-Georgia is contained in a paper presented by S. H. Chasen at the 1965 Fall Joint Computer Conference in Las Vegas and in a book, *Interactive Graphics for Computer-Aided Design* by M. David Prince, published in 1971.[37]

Lockheed-Georgia installed a UNIVAC 418 computer with a Digital Type 340 display in 1963. The UNIVAC 418 was a relatively new 18-bit machine with a four microsecond add time and hardware floating point. Since there was little existing interactive graphics software that could be utilized for this system, the Lockheed-Georgia programmers had to develop the software from scratch. It appears from Chasen's paper and Prince's book that they closely followed other graphics projects such as Sutherland's Sketchpad and the work Ross and Coons were doing in association with MIT's Project MAC.

The Lockheed  system used a light pen as did most graphics projects of that era along with a 28-button function box. The purpose of each button was specific to the application currently being used. The software was capable of creating and editing three-dimensional models which could be viewed in a traditional three orthogonal and one perspective view format. Isometric views were also supported using a separate program. The creation and editing capabilities for working in three-dimension space were fairly basic – points, lines circular arcs, rotation about an axis perpendicular to the view, and scale change. When functioning in a two-dimensional mode, additional graphics capabilities such as constructing a circle tangent to two circles were available. Given the constraints of the Type 340 display, the models and images that could be handled were quite limited.

The company had a team of about 20 programmers working on the project. There was a long-range group working on basic graphics functionality and a near-term group working on applications that were intended to be operational in 1965. The latter group

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[36] Cohen, Dan and Lee, Theodore M.PG. – *Fast drawing of curves for computer displays* - Proceedings of the 1969 Spring Joint Computer Conference, Boston Massachusetts 1969 Volume 34, AFIPS Press, pg. 297

[37] Chasen, S.H. – *The Introduction of Man-Computer Graphics Into the Aerospace Industry* - Proceedings of the 1965 Fall Joint Computer Conference, Las Vegas, Nevada 1965 Volume 27 Part 1, Spartan Books, pg. 883 and Prince, M. David – *Interactive Graphics for Computer-Aided Design* – Addison-Wesley Publishing Company, 1971

 

was working on two projects, the ability to mathematically define aircraft surfaces (technology which is still evolving today) and the ability to produce NC control tapes for two-dimensional milling machines.

While Lockheed-Georgia was using APT for part programming, the graphics development team believed that they could improve the process using interactive graphics. The initial software for doing so was fairly basic. Once the geometry of the part was defined, the user would indicate the path the milling machine should take segment by segment as shown in Figure 4.8. The first production part was a rudder control pulley for the C-141 aircraft which was produced on the Univac 418 in 1965. This may well have been the first part programmed using computer graphics in the aerospace industry.

The program for generating tool paths was called PATH. The user was able to define the starting location of the tool and the depth of the cut along with the radius of the tool. With that information, each surface to be machined was selected by the user and the information necessary to direct the tool would be calculated by the software, bypassing the APT system then being used.

Chasen was very aware even at this early stage in the development of CAD/CAM systems that the technology would have a significant impact on how engineering design and manufacturing would be practiced in the future. “For example, current design practices require a sequence of relatively autonomous operations….With computer-aided design, the team concept may be altered considerably.”[38] Truer words have rarely been spoken in this industry.

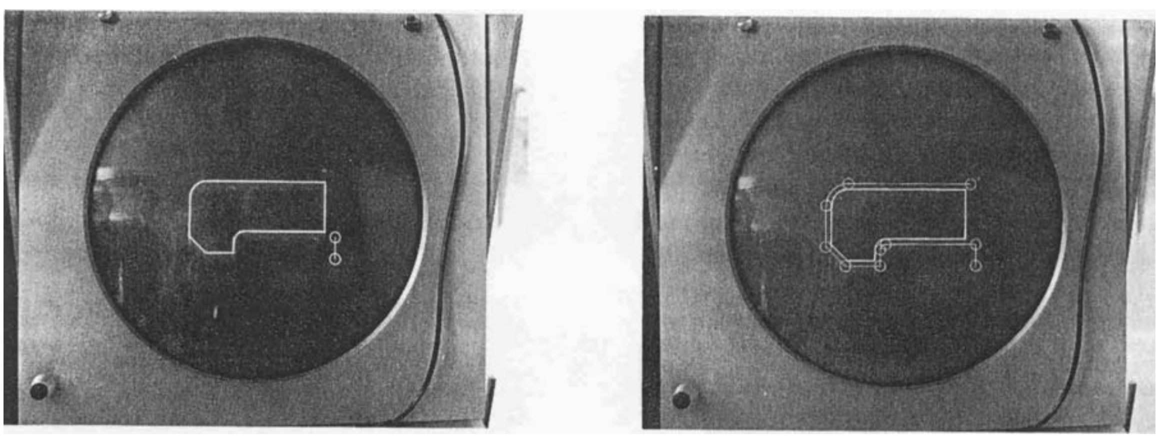

Figure 4.8
Lockheed-Georgia NC Example Showing Initial Part on Left and Tool Path on Right[39]

Of particular interest is Chasen’s comments on the relationship between aerospace firms and computer manufacturers in regards to the development of interactive graphics systems. He felt that the computer manufacturers should concentrate on developing hardware and leave the development of graphics applications to the likes of Lockheed-Georgia. “Though Lockheed-Georgia may use some of the manufacturer’s software features when they become available, we believe that the creation of our own program

[38] Ibid., pg. 891
[39] Ibid., pg. 889

 

system for our own applications offers the greatest flexibility and, therefore, the greatest success in long term operations."[40]

The work Chasen described showed that a computer dedicated to a single display console was frequently idle between user requests for action. The company felt that a single computer could therefore handle a number of such consoles. In the fall of 1965 Lockheed-Georgia placed an order with Control Data Corporation for a CDC 3300-based system with three 22-inch Digigraphics display consoles. The CDC 3300 was a fairly fast computer with a 2.75 microsecond add time and a 32K word main memory – each word 18 bits in length. The Digigraphics displays were refreshed from a six-track drum storage device which rotated every 33 milliseconds. Each track stored 10,000 words which resulted in the system's ability to display far more complex drawings than the DEC Type 340 used previously. A second two-terminal system was installed to support research work at Lockheed-Georgia.

As described by James Kennedy in a paper presented at the 1966 Fall Joint Computer Conference in San Francisco, Lockheed-Georgia stripped out part of the software Chasen described earlier and used it as the basis for a two-dimensional drawing system.[41] Most of Kennedy's paper dealt with enhancements Lockheed-Georgia made to the CDC operating system to provide an improved time-sharing environment rather than describing the applications the system was applied to. The resulting software, the Graphic Time Shared System (GTSS), is described in greater depth in Prince's book.

The key application was the design of parts that were subsequently produced using NC machine tools. According to Prince, critically needed parts could be turned around in about 24 hours as compared to a week or more using APT. Over 50 parts were designed and programmed using this system for the C-5A then being built by Lockheed.

The CDC system was supplemented by an IBM System 360/50 computer with three 2250 display terminals in 1968. It is interesting to note that there seems to have been very little coordination between Lockheed-Georgia and Lockheed-California during this period. The Lockheed-California CADAM software is discussed in depth in Chapter 13.

**IBM Develops hybrid circuit design system**

Although this book focuses on mechanical and to a lesser extent on AEC applications, the work done at IBM on developing a hybrid circuit design system in the mid-1960s is important because it is a good example of IBM's focus on user interaction issues that eventually became important in its work with Lockheed-California and CADAM. IBM System 360 computers were constructed primarily of small hybrid integrated circuits about a half inch square. Each circuit typically consisted of several discrete transistors and/or diodes, several resistors and the interconnecting circuitry. The manufacturing process for these modules involved a number of steps that required producing several graphical layout patterns or masks.

The system developed by IBM at its Hopewell Junction, New York facility did not have a specific name associated with it – perhaps one reason why the company's pioneering work was not been more widely recognized in subsequent years. The

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[40] Ibid., pg. 887

[41] Kennedy, James – *A System for Time-Sharing Graphic Consoles* - Proceedings of the 1966 Fall Joint Computer Conference, San Francisco, California 1966 Volume 29, Spartan Books, pg. 211

 

hardware configuration for this system consisted of a relatively slow IBM 1620 Mod II computer which had an add time for a pair of five-digit numbers of 140 microseconds, two IBM 1311 disk drives, each of which stored 2 MB of data and a 19-inch display with function keys and a light pen. The display had its own memory and was able to display 1,023 straight line segments, about 5,000 characters or a combination thereof. Hard copy was produced on 29-inch incremental plotter.[42]

The user interacted with the circuit design and layout software by pointing the light pen at “light buttons” displayed on the bottom of the display surface as shown in Figure 4.9. The process proceeded in two major steps. The first phase was to define a circuit schematic. With earlier electronic design software, this step had been done by reading data entered on punch cards. Interactive circuit design used the light pen to select circuit components, place them in a logical arrangement and then define the connections. Values for the different circuit elements were then entered manually using the console keyboard. This was followed by using a program running on the 1620 to calculate the required size of each resistor, a key step in designing a hybrid circuit.

The second phase of the design process was to create the physical layout of the hybrid circuit itself. The software created a component list from the schematic data and displayed the list on the screen along with a blank module substrate. The user then selected items from this list and placed them on the substrate blank. The software ensured that all the items in the component list were placed on the substrate and that the operator did not add anything that was not defined in the schematic diagram. As each component was placed by the operator, it was removed from the list, clearly indicating to the operator those item left to be placed.

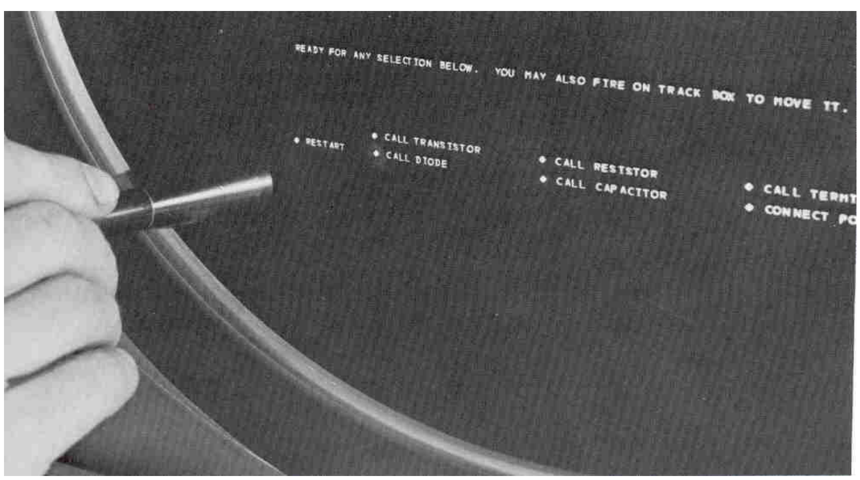


Figure 4.9
Display Screen Being Used to Define Logic Diagram[43]

[42] Koford, J.S. et al – *Using a Graphic Data-Processing System to Design Artwork for Manufacturing Hybrid Integrated Circuits* - Proceedings of the 1966 Fall Joint Computer Conference, San Francisco, California 1966 Volume 29, Spartan Books, pg. 229
[43] Ibid., pg. 235

As the components were placed, the software generated point-to-point connections between components as defined by the schematic diagram. The operator could then clean up the interconnections by inserting break or bending points in the lines. These lines could be displayed as single line interconnections or the actual width of the lines could be displayed as illustrated in Figure 4.9. Once the layout was completed the data could be preserved on punch cards or the artwork for the circuit masks plotted on the attached plotter.

According to Koford, "…the development of the system described in this paper has shown beyond a doubt that the use of graphic data processing techniques can result in significant improvements in both the ease and the speed with which integrated circuit artwork may be produced."[44] As the electronics industry moved from using hybrid circuit modules to more complex integrated circuits, the use of computer graphics for producing production artwork would grow rapidly.

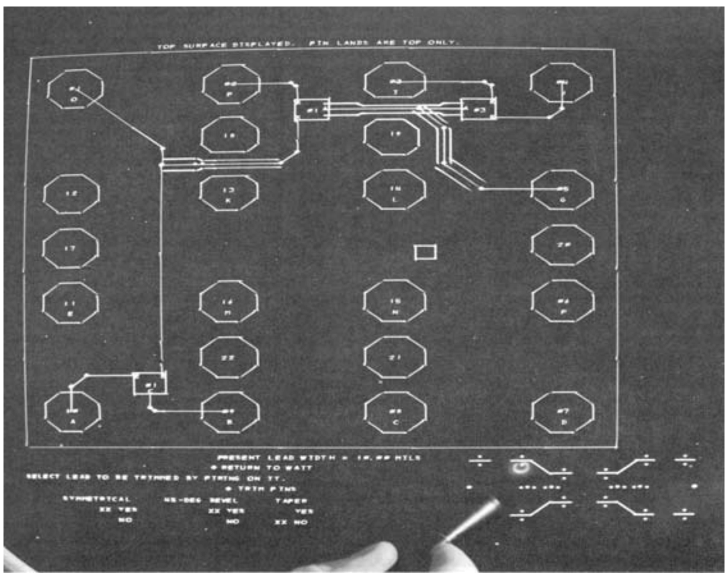


Figure 4.10
Display of Hybrid Circuit Layout Showing Actual Width Interconnections[45]

By the early 1970s, artwork production systems for integrated circuits and printed circuit boards would be a major source of income for Calma, Computervision, Gerber and Applicon as described in subsequent chapters. For the most part, these systems focused predominately on the geometric artwork portion of the task and it would be another decade before companies such as Mentor Graphics and Cadence began to link schematic design with artwork production into a single system. The technique of defining a schematic layout and then designing the physical implementation of that layout using the data in the schematic layout to verify the physical design was extensively applied in process plant design by Intergraph and others.

[44] Ibid., pg. 245
[45] Ibid., pg. 241

 

**General Motors defines graphic requirements**

In a paper presented at the 1967 Fall Joint Computer Conference in Anaheim, California, John Joyce and Marilyn Cianciolo of the General Motors Research Center in Warren, Michigan provided an excellent summary of the desirable characteristics of interactive graphic systems. Although not limited to engineering design applications, their comments concisely described the key features a CAD system should have with a special focus on user interface issues. This work was based on experiments conducted at the research center using three different hardware configurations – the original DAC-I system described in the previous chapter followed by an IBM 360/50 with 2250-I displays and an IBM 360/67 with 2250-III displays. It should be noted that the authors comments were predicated upon the use of stroke refresh displays and light pens for user interaction.

Many of the statements made by Joyce and Cianciolo would eventually become features of commercial CAD systems including those using storage tube graphics and tablets. Some of their key points were:[46]

- Typical users will have little computer experience.
- Systems must be implemented such that users can do productive work for several hours per day.
- Fast response time is a key factor in implementing an effective application.
- The use of alphanumeric data to drive these systems should be minimized.
- Many errors can be eliminated by allowing just syntactically correct data to be selected.
- Data of similar types should be able to be grouped together. Although not mentioned in this paper, the concept eventually led to use of layers in most CAD systems.
- Selective brightening of data is a powerful feedback mechanism. Shading would be useful for user understanding of three-dimensional surfaces. Blinking of displayed entities was also discussed as a tool to attract the user attention.
- Graphical communication systems must be natural and convenient to use.
- The number of steps required to accomplish a particular task should be minimized.
- Application programmers should be able to selectively permit or disable the use of different input devices.
- The display controller should be able to identify a selected graphical entity without requiring the host computer to perform extensive database searches.
- No artificial restraints should be placed upon the amount of data displayed other than the physical limitations of the hardware.

Description of databases assembled in ring structures closely followed the work of Ross and Rodriquez described in the previous chapter. The capabilities described in

[46] Joyce, John D. and Cianciolo, Marilyn J. – *Reactive displays: improving man-machine graphical communication* - Proceedings of the 1967 Fall Joint Computer Conference Anaheim, California 1967 Volume 31, Thompson Books, p 713

this paper were implemented at GM in a series of subroutines written in PL/1. Applications could be implemented by calling these subroutines for maintaining displayed images and interactive graphic tasks such as light pen selection of entities.

 

# Chapter 5

# Civil Engineering Software Development at MIT

*Author's note: I worked as an undergraduate and graduate research assistant in the MIT Civil Engineering Department from September 1957 to June 1961.*

While MIT is often seen as a major center of research regarding mechanical engineering design software it was also where significant early civil engineering software was developed. The bulk of this work was done in the late 1950s through the mid-1960s under the leadership of Professor Charles L. Miller. He was one of the first to see the potential of the relatively new computer when he joined the faculty at MIT in 1955 as a 25-year old assistant professor of surveying. In this role he soon became head of the MIT Photogrammetry Laboratory. Surveying instruction at MIT began changing under his guidance from its traditional instrument orientation to teaching students how to process and analyze spatial data.[1]

Surveying as a technical skill began evolving in the early 1700s at the same time that forerunners of modern instruments such as the transit and level became available. One of the first surveyors of repute in the United States was a young George Washington. The vast open spaces of the American continent led to the development of a rectangular grid system for the emerging United States and served to foster a growing surveying profession. To a great extent, surveying and civil engineering were closely intermingled until the early 1900s. As structural engineering, highway design and sanitary engineering

Figure 5.1
Professor Charles L. Miller and Students [2]

[1] Surveying had long been a key component of civil engineering education since many civil engineering graduates started their careers doing surveying work. Until 1950, MIT's Civil Engineering Department ran a surveying summer camp called "Camp Tech" for undergraduates in East Machias, Maine. To quote the department's Spring 2002 newsletter: "Installing a benchmark is no longer considered a mandatory job skill for graduates."
[2] MIT Civil and Environmental Engineering. Photograph is probably around 1965 or 1966.

 

became part of the civil engineering curriculum, surveying became more a specialty of its own. In recent years, aerial photography, laser distance measuring, data recorders and Geospatial Positioning Systems (GPS) have replaced traditional surveying instruments and the practice of professional surveying has become highly specialized.

**New techniques for acquiring terrain data**

When Miller first joined the MIT faculty there were two research areas that he felt needed to be explored. One was to develop better ways of acquiring spatial data with the focus being on utilizing new stereoscopy techniques and the other was utilizing emerging computer technology to process this data. Photogrammetry is basically the science of making spatial measurements using photographs while stereoscopy is the viewing of these photographic images in three dimensions. Using overlapping aerial photographs and a variety of projection devices it is possible to create contour maps and to measure three-dimension ground coordinates without having to physically survey the area except for establishing a small number of control points.

In the mid-1950s, the Photogrammetry Laboratory installed the stereoplotter shown in Figure 5.2. A pair of overlapping aerial photographic transparencies were placed in the unit's overhead projectors and carefully aligned so that a focused image was projected on the table. A viewing device enables the operator to determine elevations by adjusting a dot of light so that it appeared to be on the terrain surface. At the same time, a geared mechanism indicated the X and Y coordinates of that location. Recording a sufficient amount of data to be used as input for a computer program that calculated earthwork volumes was a very time consuming process. Under the direction of Dan Schurz, a graduate student, the laboratory began building a device that would convert stereoplotter data to three-dimensional coordinate values and output that data using a keypunch machine. This device became operational around 1959 or 1960.

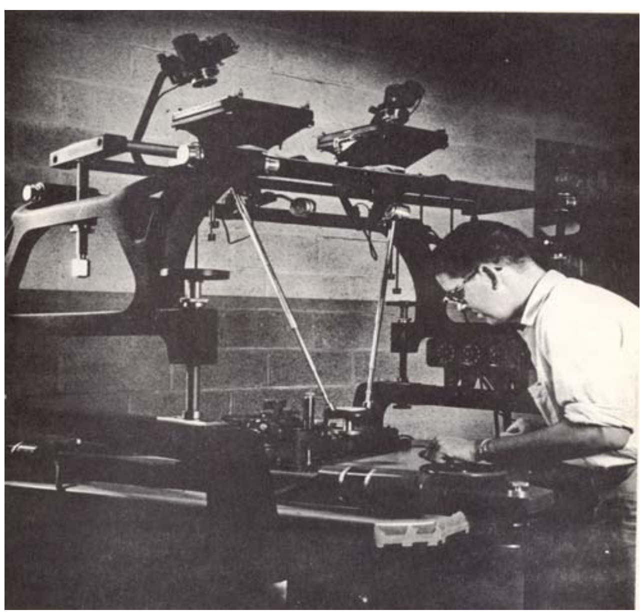

Figure 5.2

 

MIT Photogrammetry Laboratory Stereoplotter Being Operated by Bob LaFlamme[3]

The first software package developed at MIT about which I have been able to find information was a Borrow Pit Program (i.e. calculate the volume of material removed from a gravel pit or similar such area) written for the IBM 650 computer in 1956 by Paul O. Roberts[4] who was a research assistant at the time. He worked with Vincent J. Roggeveen, an assistant professor of transportation engineering. It does not appear that Miller was engaged in the department's earliest computer activity. The IBM 650 was a drum computer that had less computational power than a current cell phone. Data input was in the form of 80-column punch cards and the output was also on punch cards. This computer was slow, awkward to use and dependent upon have the punch cards in the correct sequence, but it was a start.

Roberts' work was part of a Joint Highway Research Project between the MIT Department of Civil and Sanitary Engineering[5] and Commonwealth of Massachusetts Department of Public Works. The Borrow Pit Program used data directly from surveying field books keypunched into punch cards. This data was read by the computer and the terrain profile for the original ground and the current level of the borrow pit were determined. The area of each cross section was calculated and the volume was calculated using a technique called the average end area method. The results were punched into cards by the 650 computer and printed on a machine that in those days was called a tabulator. The input punch cards contained 80 columns of data and a panel with control wires was needed so that the 650 computer could understand what the different fields of data represented. A similar type of control panel was needed for printing the program's output. In a few minutes, this program handled computations that would have taken a technician many hours to accomplish.[6]

Miller focused the Photogrammetry Laboratory's efforts initially on the development of a series of highway design programs built around the concept of a Digital Terrain Model and the building tools for acquiring digital terrain data either photogrametrically or by digitizing existing contour maps. By 1956 the U. S. Bureau of Public Roads (the forerunner of today's Federal Highway Administration) was funding a significant portion of this work. One device built by Phil Gladding, with some help from me, was a device for recording terrain values from contour maps and punching this data directly on punch cards. See Figure 5.3.

### Digital Terrain Model concept

The DTM concept was a significant breakthrough in how engineers thought about highway location and the work that went into establishing horizontal and vertical alignments and calculating earthwork quantities. The traditional manual approach for highway design involved selecting a preliminary horizontal alignment and the acquiring terrain elevations along cross sections perpendicular to this alignment from either field surveys or existing contour maps. This technique had evolved over nearly 100 years and

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[3] Miller, C. L. and LaFlamme, *The Digital Terrain Model – Theory and Application*, MIT Photogrammetry Laboratory Publication 117, March 1958

[4] As an assistant professor of civil engineering, Roberts was the my masters thesis advisor in 1961

[5] Now the Department of Civil and Environmental Engineering

[6] MIT Joint Highway Research Project Research Report No. 20, Revised Second Edition, September 1957

 

worked fairly well as long as no significant adjustments were made to the alignment. If they were, then new cross section terrain data had to be acquired.

Figure 5.3
Digital Terrain Data Recorder[7]

The DTM method was predicated upon the concept that the surface of the ground could be statistically represented by a large number of XYZ data points. These could be based either on an existing coordinate systems such as a state plane system or an arbitrary coordinate system defined for a given project. Fundamentally, all contemporary highway design applications use this approach today. The implementation used at MIT during this period involved establishing a project-specific baseline and then recording terrain data along scan lines. The elevation data was recorded at either given intervals along the scan line or at predefined elevations corresponding to contour elevations on a hard copy map.

Miller and his team of research assistants understood the statistical significant of terrain data and the fact that small random errors would not affect overall results. The first series of highway design programs developed at MIT were called the Digital Terrain Model System. There were nearly a dozen separate programs in this suite of software including terrain data editing, horizontal alignment, vertical alignment and earthwork calculation. The reason for the large number of programs had to do with the fact that they were written for the IBM 650 computer which was the typical machine used by state highway departments at the time. The 650 had limited capacity to store programs and data. As a result, each program had to be loaded into the computer each time it was run along with appropriate design and terrain data. The punch card output of one program became to input to the next program.

As an example, one program was used to calculate the centerline of a highway using Points of Intersection (known as P.I.s or the coordinates of where two straight sections of the highway theoretically intersected) and the radii of the curves associated with those P.I.s. The output of this program was a complete definition of the roadway

[7] *Technology Review*, June 1959

 

centerline. The output was then used by a different program to calculate the geometry that defined offsets from the centerline such as the edges of a median or the outer edges of the roadway. The next step was to use this data to calculate the vertical alignment of the roadway. Finally, earthwork volumes could be calculated by another program.

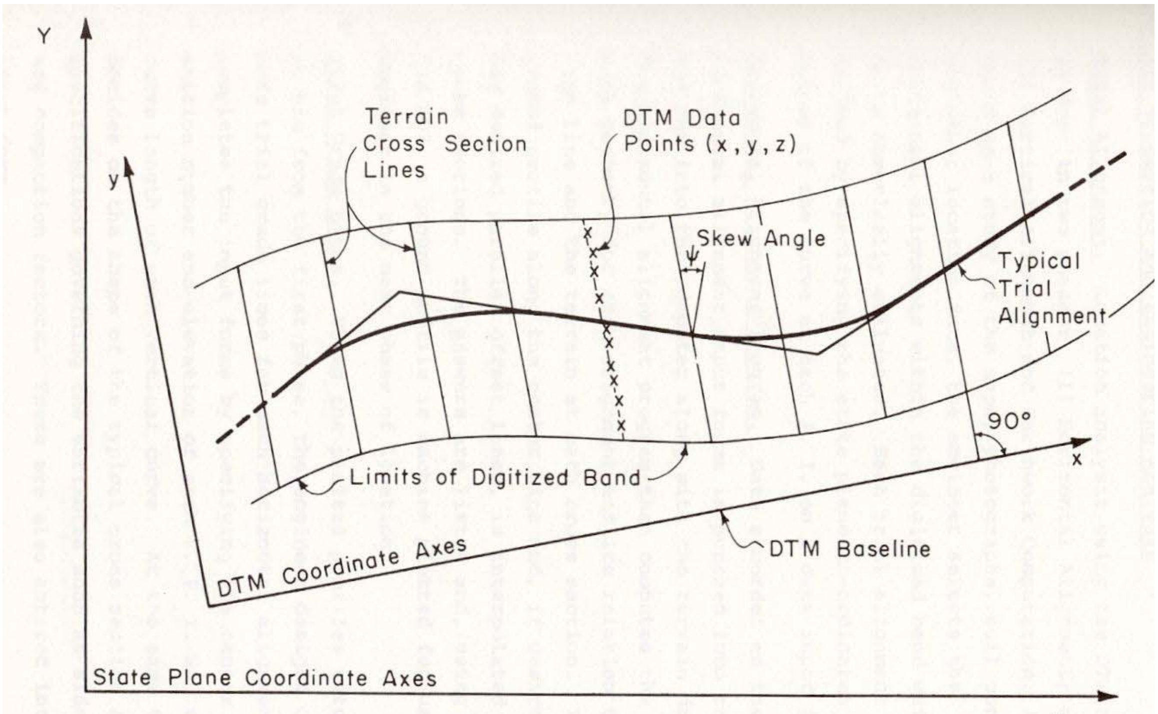


Figure 5.4
Digital Terrain Model[8]

These programs went through several iterations and by 1960 a new suite intended for highway location analysis and preliminary design was also available from MIT. Known as DTM II, it consisted of a Terrain Edit Program (TD-5), a Horizontal Alignment Program (HA-5) and a Roadway and Earthwork Program (EW-5). This software was designed by Paul Roberts and Bob LaFlamme with much of the actual coding done by Roger Baust, Dwight Rehberg and R. B. Doggett with testing done by an experienced highway engineer and surveyor, Ed Newman. Newman worked with Miller for over 30 years at MIT and CLM/Systems as discussed below.

The DTM System was far from a perfect solution - data acquisition was time consuming, the programs were slow and susceptible to errors in sequencing the input data and there were few machines available capable of plotting the output. All this began to change rapidly around 1960. The MIT Civil Engineering Department installed a higher speed computer, an IBM 1620, CalComp introduced the first plotter designed specifically for plotting digital computer output and new high level programming languages such as

[8] *Digital Terrain Model System Manual of Electronic Computer Programs for Highway Location and Design*, November 30, 1960

 

FORTRAN became more readily available. Around 1960, the Photogrammetry Laboratory became the Civil Engineering Systems Laboratory.

**Development of COGO**

Miller is perhaps best known in the civil engineering community as the original developer of COGO – the coordinate geometry technology that is at the core of nearly all surveying and roadway design software today. COGO was one of the first examples of what is referred to as a "problem oriented" language. It enables a user to solve a wide variety of geometry problems by defining the interrelationships of points, lines, angles and curves. Interestingly, while Miller provided general direction for most projects under his supervision, COGO was his own personal project.

In simple terms, a COGO statement defined a specific geometric entity such as a point on the ground, a length between two points or an angle between two lines. A new point was calculated by telling the computer it was located a specific distance in a specific direction from a previously defined point. For example, a typical COGO statement might read:

**LOCATE POINT 2 FROM POINT 4, DISTANCE 125.16, BEARING N45 15 20 E**

Eventually, a shorthand version of COGO was developed so that this statement could be written:

**LOC 2, 4, 125.16, N45 15 20 E**

Far more complex series of calculations could be initiated including complete traverses and highway intersections. These statements were entered into the computer via punch cards or other means and the COGO program would sequentially step through the statements, calculate the requested data and save it.

An experimental predecessor to COGO was written for the IBM 650 and given the intriguing name of *Tricky Dicky Traverse*. I have never been able to determine where that name came from other than the fact that Richard Nixon was vice president at the time. Miller sketched out the basic concept for COGO on the back of an envelope one weekend and soon began implementing it on the new IBM 1620 computer.[9] In the 1960 time period, Miller was also doing some consulting work for the Puerto Rico Bureau of Highways and the first version of COGO was installed in mid-1960 on a 20K character 1620 that they had recently installed. Subsequently, a research version was installed on MIT's 1620. This was followed by implementations on Digital minicomputers and IBM mainframes. Copies of these various implementations were submitted to a number of software libraries and became public domain packages.

Interestingly, Miller claims that COGO was attacked by the "computer establishment." He went on to state: "Only the users applauded. It was said that COGO would make it possible for ***just anyone*** to use the computer. In essence, the opposition to COGO was that it was too ***user friendly***…"[10]

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[9] The MIT Civil Engineering Systems Laboratory received one of the first 1620 computers produced by IBM. It arrived damaged and was replaced a few weeks later by a new machine. Interestingly, the shipping container had NASA's Marshall Space Flight Center marked out and the shipping label changed to MIT.

[10] Miller, Charles L., *The COGO Story – An Odyssey*, CLM/Systems Publication, 1989

 

The concept of problem-oriented languages began to be explored by others. Independently of MIT, Dr. Steve Fenves implemented a structural engineering program, STRESS (STRuctural Engineering System Solver) that used a similar problem-oriented language methodology.

**Development of ICES**

Although he was just an associate professor without tenure and had never earned a doctorate, Miller was made chairman of the Civil Engineering Department in 1961, a position he held until 1969. At 32, he was the youngest person to ever hold this position and quickly set out to bring the department into the modern computer age. One of his first steps was to bring Fenves on as a visiting professor.

The department's early efforts to create a new highway design methodology eventually led to a major development project begun in 1964 called ICES or Integrated Civil Engineering System[11], which included popular programs such as ROADS, STRESS and STRUDL as well as COGO. The MIT development personnel were strong proponents of problem oriented languages and that focus continued with the ICES project. Led by Daniel Roos and Joe Sussman, the development team created its own programming language, ICETRAN, a civil engineering variant of FORTRAN and an engineering software-oriented operating system. Miller liked to refer to this group of undergraduates and graduate students as his "COGO kids."

A basic ICES premise was that in order for an engineer to address a complete problem solution, the results from one application task needed to be available as input to a subsequent task. Discussing an engineer's use of ICES Roos commented: "At any point in his problem solution he can leave one subsystem, enter another to perform calculations and then reenter the original subsystem using the results just obtained."[12]

Each application program (subsystem in MIT terminology) enabled an engineer to define a series of tasks that were to be applied to that problem's data set and to do so in terms that were meaningful to the engineer. Much like geometry problems could be defined with COGO statements such as what was shown above, structural, soil engineering or highway design problems could be defined using terms relevant to that type of engineering. One advantage of this approach was that if data items changed or the engineer wanted to change the problem definition, these source statements could be easily edited and the problem re-run.

An application subsystem consisted of a series of subroutines that executed the tasks defined by each problem statement. These were not huge monolithic programs. Rather they were a series of software modules written in ICETRAN. Furthermore, ICETRAN itself was not a software compiler but was what programmers call a "pre-compiler." To create an application subroutine, a programmer would write the necessary code in ICETRAN which would then be converted by another program into standard FORTRAN source code statements. That FORTRAN code was compiled to create the application subroutine. ICETRAN software was also implemented to handle the

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[11] In addition to the U. S. Bureau of Public Roads and the Massachusetts Department of Public Works, ICES sponsors included IBM Corporation, the National Science Foundation, McDonnell Automation Company and the Ford Foundation.

[12] Roos, Daniel, *An Integrated Computer System for Engineering Problem Solving*, AFIPS Conference Proceedings, Volume 27, Part 2, Thompson Book Company, 1967 Pg. 152

 

management of complex data arrays, a task that the basic operating systems at the time did not do very well.

To solve a design problem, the engineer would define the data and the tasks to be applied to that data in a series of problem oriented statements. The ICES executive program processed these statements, checking for errors and inconsistencies. The software would then call individual subroutines to execute the statements. One statement was completely processed before the next one was executed, although this was typically transparent to the user.

By the mid-1960s, civil engineering software development at MIT was being done on an industrial strength computer, an IBM System 360 Model 40 with a 128K (32-bit words) memory and a pair of disk drives. Rather than using punch cards, programmers and application users began using alphanumeric terminals although early versions of ICES applications still envisioned the use of punch cards for data input and printed output.

STRUDL (STRUctural Design Language) development was led by Professor John Biggs[13] and Robert Logcher who later became a professor at MIT. This software, which was first made available to users around 1967, was a significant extension to the earlier STRESS program in that it incorporated ICES capabilities for managing data and other functions. Users could define two and three dimensional framed structures with rigid or pinned joints. An engineer could define the basic structure, perform a preliminary analysis and subsequently refine the structural design by simply changing the location of joints or the size and orientation of members. A simple STRUDL statement might read:

**JOINT 2 COORDINATES X 10.5 Y 20.6**

As with COGO and other ICES programs, a shorthand version of these commands was also provided. Analysis output was stored so that the design engineer could request that additional information be printed without having to rerun the analysis.[14]

ICES ROADS was developed during the same timeframe as STRUDL. The key individual responsible for ROADS was John Suhrbier assisted by John Prokopy, Edward Sullivan and Wayne Pecknold. ROADS consisted of four major modules. The first handled the creation of a terrain database, a necessary step in order to do any design work. While there were specific commands for inputting terrain data, other programs could also format bulk input of this data. The second module was for defining the horizontal and vertical alignment of the proposed highway while the third modules was used to define roadway cross sections and calculate earthwork volumes. These modules worked closely with ICES COGO and, in fact, many COGO commands were duplicated within ROADS although there was only a single copy of the COGO code loaded on the computer system being used.

The fourth module was for the simulation of vehicle performance. A number of commands were available to describe the subject highway including lane descriptions, traffic signals and intersections. The user could then define the types of vehicles and the

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[13] Professor Biggs was my structural engineer instructor the late 1950s.

[14] Biggs, John M. and Logcher, Robert D. – *ICES STRUDL I – Structural Design Language – General Description* – MIT Structures Division and Civil Engineering Systems Laboratory, September 1967

traffic volumes at different times. The software would then calculate expected vehicle operating costs and average speeds. Overall, the command language for ROADS was far more complex than for most other ICES applications. One surprising aspect of ROADS was that there did not seem to be any way of producing plotted output from this package other than what were called "character plots" on an alphanumeric printer.[15]

Gradually more applications were added to the ICES system including TRANSET for transportation network analysis, SEPOL and LEASE for soils engineering, BRIDGE for bridge design and PROJECT for project management.

One of the strengths of ICES was that users could extend the capabilities of the individual programs using the same software development tools used by the system developers - not unlike the use of Bentley Systems' MicroStation Development Language (MDL) years later. The major shortcoming of ICES was that it did not incorporate interactive graphics - it was a few years too early for that technology to be practical.[16]

Miller's observation of the impact ICES is interesting:

> "ICES achieved considerable success as an advance in applying computer technology….However, as an integration of the civil engineering profession, ICES was not very successful. Some observe – perhaps correctly – that I confused ICES with my attempts as department head to reorganize and revitalize the civil engineering department at MIT – a partial, through controversial, success."[17]

**Miller moves on from MIT**

In 1968 Miller became head of MIT's Urban Systems Laboratory and continued as director until 1977. Also in 1968, Miller was appointed by President Nixon to head a Transportation Task Force. By the late 1960s the ICES project started winding down as people such as Roos, Sussman and Logcher moved on to new challenges. Miller was named associate dean of engineering in 1970 and was the interim director of the Charles Stark Draper Laboratory for one year while it was undergoing the transition from being the MIT Instrumentation Lab to an independent research facility.

In 1977 Miller left MIT and focused his activities on CLM/Systems, a software and civil engineering consulting firm he had earlier established in Tampa, Florida. The company developed a series of civil engineering software applications including COGO, TOPO for processing topographic data and ROADS for highway design. In 1986 these were integrated together in a product called CLM CEAL (Civil Engineering Automation Library) which was used by a number of state highway departments and civil engineering firms.

CLM/Systems actually started out as CLM/Research in 1955 when Miller first joined the MIT faculty and needed a vehicle for doing consulting work beyond the research activities of the Photogrammetry Laboratory. The name was changed to

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[15] Suhrbier, John H., et al – *ICES ROADS I – Roadway Analysis and Design System – Engineer's Reference Manual* – MIT Civil Engineering Systems Laboratory, March 1968

[16] Roos, Daniel, *An Integrated Computer System for Engineering Problem Solving*, AFIPS Conference Proceedings, Volume 27, Part 2, Thompson Book Company, 1967 Pg. 151

[17] Miller, Charles L., *The COGO Story – An Odyssey*, CLM/Systems Publication, 1989

 

CLM/Systems in 1968. Until about 1981 the company was primarily a consulting company working on urban planning studies and assisting clients with implementing computer technology. At that point, Miller decided that there was a need for a new generation of civil engineering software and set out to create it.

The company soon grew to about 30 people, none of whom were classified as sales or marketing. The software was sold primarily by word-of-mouth. CEAL enthusiasts existed in numerous state and county highway departments including Georgia, Washington, New York, Dallas and Los Angeles. For a period of time, McAuto sold CEAL as an alternative to the MOSS software from MOSS Systems in England which it had supported since the mid 1980s. CLM/Systems also had a close working relationship with Intergraph and even sold a product called CEALstation which was a combination of CEAL and MicroStation.

For more than two decades after leaving MIT, Miller was still referred to as "Professor." He always wanted to be the teacher. Following are his guidelines for the successful use of CEAL – they could apply to any engineering automation software package.

- "Don't try to force CEAL into being something it is not and don't wait for the next release. USE CEAL AS IT IS.

- If you try to make CEAL act like some other package you are acquainted with, you will fail. Every software package, like every person, has its own 'personality.' You cannot change it without grave consequences.

- Don't fight the system. Learn to use it on its own terms. You can be creative, clever, imaginative, and capable with CEAL, but you cannot be arrogant.

- CEAL is a very dynamic system under continuous development. There will always be another release on the way. But, to wait for it would be fruitless. You will wait forever for the next release.

- In the meantime, the current release of CEAL contains more capability than any user can master in a lifetime. Best to get on with using the tools at hand."[18]

By the mid-1990s CEAL had become a well rounded civil engineering application that was available on a wide range of engineering workstations and DOS-based PCs. By 1995 the software sported a graphics interface although it was not up to speed with competitive products in this regard. The price for CEAL (including COGO) ranged from $8,000 for a single license to just $1,500 per license on orders for more than 100 copies.

While there never was any question about the quality of this software, the company rarely had revenues much over $1 million in the early 1990s (earlier it had revenues over $2 million when it was selling turnkey systems consisting of both computer hardware and software) and by 1996 it had slipped into a death spiral. There

[18] *A-E-C Automation Newsletter*, December 1990, Pg. 5

was an attempt to sell the company as Miller's health was starting to fail. Unfortunately, there were no takers and the company just withered away over the next several years.[19]

There were probably several hundred different versions of COGO implemented by a vast array of companies and organizations, most of whom used the original version as the starting point for their development. None of these developers paid any royalties to Miller who passed away in 2000.

Many of the early participants in the DTM and ICES activity including Trond Kalstaad, Robert Logcher, Dan Roos and Joseph Sussman, stayed at MIT throughout their careers and contributed significantly to the Institute's academic excellence. Others left and expanded Miller's ideas throughout the engineering profession. Leroy Emkin went to Georgia Institute of Technology where he expanded the capabilities of ICES STRUDL and turned it into the very successful GTSTRUDL program. Barry Flachsbart went to work as manager of analysis and development at McDonnell Automation (McAuto) which licensed the ICES software and sold it in a timesharing mode well into the 1980s.

As described in Chapter 19, McAuto was probably the largest seller of ICES services. The company added dynamic capabilities to STRUDL with a program called STRUDL-DYNAL which was used to design numerous structures including the Louisiana Superdome in New Orleans, off-shore oil and gas platforms and nuclear power plants. The company implemented enhancements to ROADS and COGO and added a sanitary and storm sewer design program to the ICES suite simply called SEWER. By 1975, many McAuto customers were using graphics terminals such as the Tektronix 4010 and 4014 to interact with these ICES programs in a time-sharing mode.

McAuto also implemented a graphics program call FASTDRAW that enabled users to create input data for programs such as STRUDL and view plots of the results. Time-sharing use of STRUDL could end up being quite expensive. A complete STRUDL-DYNAL analysis of a large structure (800 joints and 950 steel members) could cost as much as $4,000.[20]

One of the most significant aspects of Miller's work and why I feel he deserves greater recognition than he has received is that he never considered the MIT version COGO to be proprietary technology – he made it readily available to the world without any restrictions. The only other similar example I can think off is Tim Berners-Lee the creator of the World Wide Web. Imagine where we might be today if these two pioneers had decided to patent their technology and required us to pay a royalty every time we designed a highway intersection or used the Web.

I was very please to accept the 2002 Ed Forrest Award on behalf of Professor Miller and his family at the A/E/C SYSTEMS 2002 conference in Dallas, Texas. This award, named after the founder of *A-E-C Automation Newsletter*, was awarded annually to an individual(s) who had made a significant contribution to the field of AEC software.

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[19] I was hired by Miller to find a buyer for his company but was unable to do so.

[20] Dallaire, Gene, *The CRT Computer Graphics Terminal: Indispensable Design-aid for Some Structural Engineers*, Civil Engineering, February 1976

 

# Chapter 6

## The First Commercial CAD System

*Author's note: After receiving my MS degree in civil engineering from MIT, I was employed by Charles W. Adams Associates and worked as a lead programmer on the system described in this chapter from June 1961 until March 1962. After two years in the U.S. Army, I returned to the company and was involved in a number of other graphics related projects until July 1969.*

Although there was a moderate amount of academic work underway by 1960 in applying computers to engineering design tasks, little of this work involved interactive graphics. What research work that was underway was not being done with the intent to produce commercial systems. The roots of today's CAD technology go back to the 1950s and the U.S. Air Force's SAGE project described in Chapter 3. The SAGE system, designed by MIT's Lincoln Laboratory, spawned several important technologies including high performance computers, large magnetic core memories and interactive computer graphics.

SAGE involved the use of CRT displays to show computer processed radar data and other information such as the location of defensive weapons. Using a light-gun device an operator could identify a specific threat and then select a defensive weapon such as an interceptor aircraft or missile to assign to that threat. Not only did SAGE result in an effective defense system, but it gave rise to a new generation of technology enterprises.

Ken Olsen, one of the key SAGE program managers left Lincoln Lab employment to start Digital Equipment Corporation, Norm Taylor went to work in a senior management role at Itek Corporation, a manufacturer of high quality optical equipment for the defense establishment located in Lexington, Massachusetts and Jack Gilmore co-founded with Charles Adams, another early Whirlwind associate, one of the earliest software consulting firms, Charles W. Adams Associates, which was located a few miles away in Bedford. In the spring of 1961, my career took an important turn when fresh out of graduate school, I joined Adams Associates to work on what was to become the computer industry's first attempt at creating a commercial CAD system.

Most histories of the CAD industry credit Ivan Sutherland with developing the first interactive graphic system for engineering design and drafting. His project, which also started in 1961, was called SKETCHPAD and was the subject of his Ph.D. thesis at MIT (see Chapters 3 and 4). Sutherland used the TX-2 computer at Lincoln Lab, a huge machine that was one of the fastest systems then in existence. While Tim Johnson expanded upon Sutherland's work to produce three dimensional data models and graphic images, the work at Lincoln Lab was never intended to end up as a commercial product. In 1968, several of the people working on subsequent TX-2 graphics projects, however, left the lab to start Applicon as discussed in Chapter 7.

**Putting the pieces together**

In late 1959, Gilmore presented the concept of using a computer graphics system for engineering design to Taylor. Taylor subsequently convinced Itek's management in August 1960 to fund the development of an interactive graphic system using the argument that it could be used to assist the company's engineers in designing optical systems and might eventually lead to a commercial product that would be sold to other companies for engineering design and drafting. The project was later named the Electronic Drafting Machine or EDM.[1]

Olsen's Digital Equipment Corporation was selected to provide the computer system, a Digital PDP-1, which had recently been introduced to the market. In fact, the actual machine used for the EDM prototype was only the second PDP-1 delivered to a commercial customer. It was an 18-bit machine with four thousand words of memory. It had no floating point hardware and input/output was limited to punched paper tape and a typewriter. Performance was about 0.1 MIPS. A PC that sells for $500 today is probably 20,000 times as fast. There was no operating system as we now know it now, just a few utility routines to help write and debug application software.

Cathode ray tube (CRT) displays in the early 1960s were nearly all stroke refreshed units. The image was stored in memory in the form of a series of line segments and control codes. It was drawn much like a pen plotter produces a drawing with incremental line segments. With the CRT beam turned on, a line is drawn from one coordinate location to another and then to another. To start a new line, the beam is turned off, moved to a new coordinate position and then turned back on. Circles, arcs and alphanumeric characters were displayed as a series of small line segments. This process had to be repeated 30 or more times per second in order to create a flicker-free image.

Itek built a custom graphics processor to produce images on a 25-inch CRT as shown in Figure 6.1. Most of the hardware design work was done by Adams, Taylor and Earle Pughe who had also earlier worked at Lincoln Laboratory. The image was stored on the peripheral or outside tracks of a large disk memory unit manufacturer by Telex Corporation of St. Paul, Minnesota. The disk was 36-inches in diameter and rotated at 1,800 rpm, providing 30 flicker-free images per second. In addition to serving as the display refresh memory, the Telex disk drive stored about 500,000 18-bit words of data.

The display data was stored in the form of four-bit bytes that either contained control information such as "start a new line" or "switch to display all following items as heavy lines." The actual line segments were stored as in the form of Delta X and Delta Y increments with a maximum display length in each axis of 0.04 inches. This resolution was sufficiently fine that relatively smooth circles and arcs as well as text could be displayed. The unit had a capacity of 20,000 bytes of control and display data.

A second key component was the light-pen used to either select items being displayed or to indicate a location on the screen. The light pen had a small micro switch which, when depressed, enabled the device to sense light. When light was sensed, an interrupt was sent to the computer and that signal could be used to identify the specific

[1] A number of the details herein come from a transcript of a panel discussion held at Digital Equipment Corporation on June 5, 1990 with Jack Gilmore and Norm Taylor participating along with several of the other individuals mentioned in this chapter.

graphical element being displayed. Additional operator interaction was via a panel of 15 control buttons.

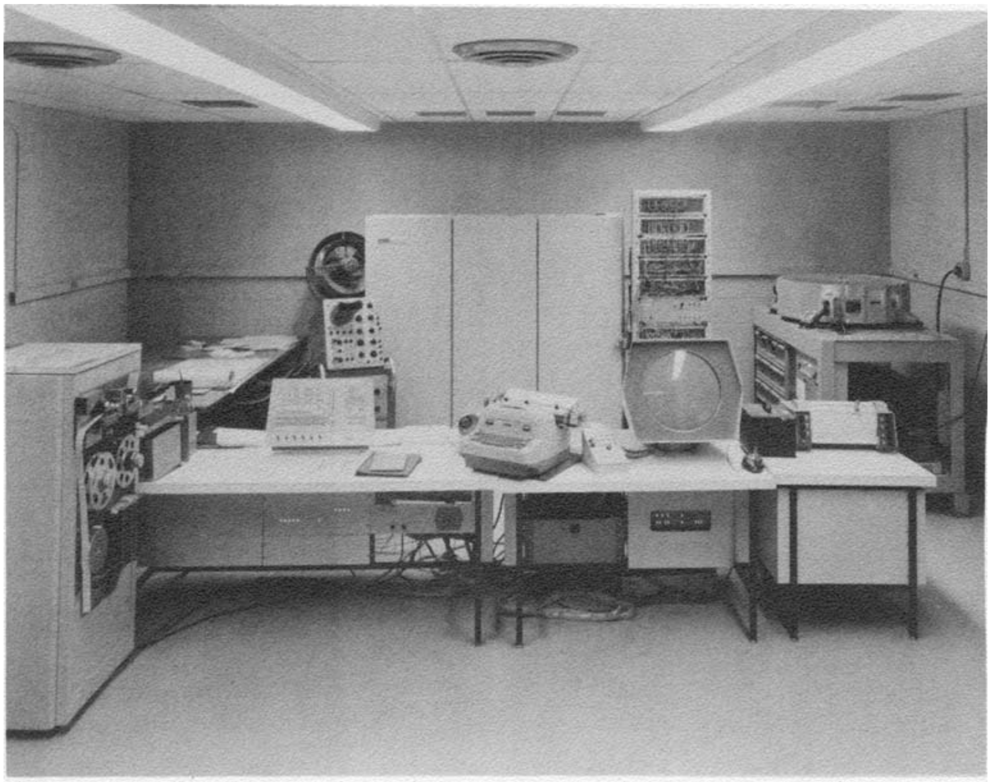

Figure 6.1
Prototype EDM configuration
(From left to right: In background – fan to keep computer cool, Tektronix oscilloscope, Digital PDP-1 computer, Itek-built display logic and Telex disk drive. In foreground – paper tape reader/punch, computer console, console typewriter, control buttons, CRT display, light pen and CalComp plotter.)

To a great extent, we were all learning this new technology as we went along. One incident involved the disk drive. This unit was contained in a Plexiglas cabinet. Either Pughe or one of his technicians cleaned the disk drive one day using an alcohol solution. Little did anyone know that the glue holding the recording head together was soluble in alcohol. When the disk was restarted, we soon had a cloud of brown dust in the Plexiglas case. The recoding head had come apart with pieces crashing down on the disk and scraping the surface. It took a few weeks to recover from that fiasco.

**Programming the EDM**

Adams Associates was retained by Itek to develop of the software used to drive the EDM. Gilmore had worked with Taylor and Olsen at Lincoln Lab and had done some graphics development on MIT's Whirlwind computer, the TX-0 and the TX-2 as described in Chapter 3. Between mid-1960 and June 1961, the basic hardware was assembled, initially at Digital's facility in Maynard and then at ITEK.

 

Little actual programming had been done when I joined Adams Associates that June. While Gilmore, Adams and Taylor had put together the overall structure of the software, they had not yet started writing code except to test some of the hardware. They both had other responsibilities at Adams Associates and Itek and I was given the task of managing software development on a day-to-day basis. The hardware was still being checked out and the EDM software was needed to confirm that the hardware, especially the custom-designed display processor, was working properly.

As mentioned earlier, the PDP-1 did not come with an operating system. Basically, we created an application-specific executive routine that handled system functions including interrupt management that today are handled by operating systems such as UNIX and Windows. We also had to program many basic graphic routines including clipping images to fit within the display area and displaying basic geometric entities. In fact, we even had to program our own trigonometric functions as well as many of the tools needed to debug our programs. Under Gilmore's direction, a very systematic methodology was implemented for programming the EDM. This was several years before the term "Structured Programming" came into vogue.

One of the senior Digital engineers was Ben Gurly who had worked with Gilmore at Lincoln Lab. One Sunday, I was trying to checked out some new software when I ran into problems with the PDP-1's paper tape reader. This was well before the days of 24/7 service so I called Gilmore at home. He called Gurley who came over to Itek. Not having any tools with him, he managed to fix the reader with a piece of scotch tape. It worked well enough through the rest of the day that I was able to get some software debugged. Unfortunately, Gurley was killed in 1964 by a mentally ill former technician named David Blumenthal.

All PDP-1 programming on this project was done in assembly language - instruction by instruction. Programs were written in long hand and then converted to punch paper tape using a typewriter-like machine called a Flexowriter. These programs were then assembled (converted into machine language) using an assembly program written by Ed Fredkin at Bolt Beranek and Newman, the proud owners of the only other PDP-1 then in existence. (BBN would later gain fame for doing much of the programming for ARPANET, the predecessor to today's Internet.) Debugging was done using a combination of console switches and the console typewriter.

**User interfaces were different**

In addition to overall management of the software development effort, I personally programmed the initial executive routines and most of the early display functions. The geometry creation was done by Dr. Murray Sherry whose real expertise was in computer-based language translation while Gilmore handled the trickiest piece of software – how to track the light-pen across a blank display to indicate a new location. This latter task was done by displaying a small pattern of dots on the screen. When the operator moved the light-pen the computer would sense which combination of dots were being recognized and then move the pattern in that direction. This process was repeated rapidly until the operator released the small switch on the light-pen, indicating that a new geometric item should start at that point. Gilmore also designed and programmed numerous other aspects of the user interface.

 

One of the executive routines I was responsible for was one which determined when the light-pen recognized the light caused by the display of an existing item. By comparing the timing of when the light was sensed with the data on the display tracks of the large disk drive described above, it was possible to identify the specific item the operator was pointing to. The process had to be done very rapidly. Looking over program listings which I still have 45 years later, I can see where I struggled to reduce the key program loop for doing this from five instructions to four because of these timing limitations.

**Creating drawings with the EDM**

Command entry was done using a combination of push buttons and light buttons. The latter involved displaying a pattern of dots on the lower part of the CRT. A template with holes corresponding to the displayed dots was placed over this part of the screen and functions were initiated by selecting one of these dots with the light pen. An early version of the overlay is shown in Figure 6.2. The operator could use this template to select specific operations, enter data such as coordinate values, select the element type to be created, enter the length of a line, or rotate a selected object. Basically, it was a fixed list of menu items although Gilmore and Taylor had suggested that the production version of the EDM could have multiple edge-lighted panels with different functions for each panel. A decade later, a number of systems used multiple menu overlays on tablets and digitizers to accomplish similar tasks.

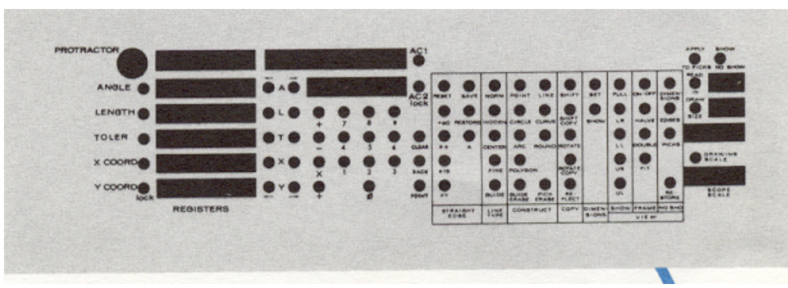


Figure 6.2
EDM Light Button Menu Overlay

The light pen software sometimes acted in unexpected ways. Prior to the first major demonstration for several senior Itek executives, Gilmore and I worked through the night correcting last minute software bugs. He did the talking while I played operator. Probably due either to nervousness or a lack of sleep, I started tapping the light pen on the keyboard. Soon, the system was off doing all types of un-requested operations and we were baffled since it had been working so well just before the visitors showed up.

It turned out that each time I tapped the light pen, it sent an interrupt to the computer which in turn tried to interpret that interrupt as a request for an operation. The software became totally confused and I believe we had to reload the system to get it to function correctly.

The EDM system was capable of drawing straight lines that could be restrained to be horizontal or vertical or lines could be inserted at any desired angle. Angles could be defined numerically or the user could select two points on the display to define the angle.

 

Points could either be established by entering coordinate values, specifying a location on the screen with the light pen or selecting the end of an existing line. The system also handled circles, arcs, polygons, free form lines and text using what was one of the first implementations of an entity table.

Objects could be moved, copied, rotated or reflected. Initially, the EDM was set up to work with A, C and E-size drawings with a rigid method of displaying one of the four quadrants of the drawing. Both the control buttons and the light button panel layout changed repeatedly during development of the EDM software as we learned what could and could not be done.

In the fall of 1961, I attended the first meeting of the Digital Equipment Computer Users Society (DECUS) at a hotel in Lexington, Massachusetts. There were probably a dozen to 20 people there. I remember the day very clearly because there was a hurricane brushing the coast of New England and the wind roared all day while we met and discussed programming the PDP-1. DECUS eventually became one of the largest such industry user groups with over 100,000 members by 1991. Digital produced 50 PDP-1s which sold for about $120,000 each.

**Marketing the EDM**

In March, 1962 I went on active duty with the Army to fulfill a ROTC commitment that could no longer be delayed. Frank Greatorex had joined the project several months earlier and he took over much of the work I had been doing. By then we were able to create, display and edit simple diagrams as illustrated in Figure 6.3. Twenty years later, Autodesk was at about the same stage with the prototype of AutoCAD. (See page 63 of *The Autodesk File*.)

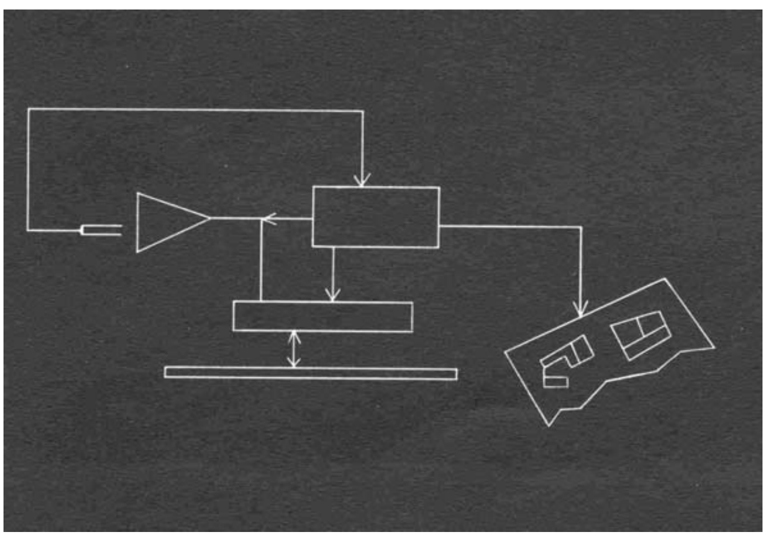

Figure 6.3
Early EDM drawing

In early 1962, Itek began actively marketing the EDM with Ed Fitzgerald placed in charge of this effort. The company prepared a sales brochure for the EDM that in retrospect was overly optimistic about the systems capabilities. One statement, however, clearly forecast where this technology might lead.

> "A capability to solve key design problems in hours instead of days or weeks by a communication network through which design conferences can be held with widely separated locations and at the end of which identical drawings, embodying agreed changes, can be made available instantaneously to all points."[2]

It sounds a lot like the collaborative design tools that were finally introduced more than 30 years later.

Itek's market positioning for the EDM was that it had broken the language barrier between the user and the computer. In their terminology, it had previously taken a programmer to reduce an engineering problem to the point where a computer could solve it. Now the user could communicate with the computer via a graphical interface without the need to be proficient in programming.

Several articles used this analogy while describing the EDM to the general public. *Time Magazine* quoted Charlton Walker, a scientist at the nearby Air Force Cambridge Research Laboratory (AFCRL), as stating "Computers don't like dealing with people….They just don't understand our language." The article went on: "With a photoelectric light pen, the operator of an EDM can formulate engineering problems graphically (instead or reducing them to equations) on a console the looks like a flat, unflickering television screen."[3] The *Time* article included a photograph of Gilmore operating the EDM that clearly shows the plastic overlay placed over the control lights displayed at the bottom of the screen.

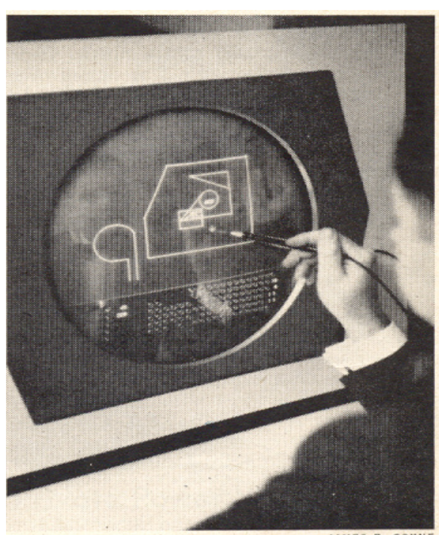


Figure 6.4
*Time* illustration showing Jack Gilmore with light pen and control button overlay[4]

[2] Itek sales brochure
[3] Beating the Language Barrier, *Time*, March 2, 1962, Pg. 74
[4] Beating the Language Barrier, *Time*, March 2, 1962, Pg. 75

 

A similar article appeared in the December 30, 1962 issue of *The Boston Sunday Herald* that also used Itek's computer language barrier theme. This article was more technical than the earlier *Time* piece in that it described in fairly clear detail the light pen tracking method Gilmore had implemented. The article also focused on reducing the volume of paper documentation.

> "It has also made possible the reduction in tons, literally, of design blueprints – which normally are needed for the construction of Space Age equipment – into a few reels of magnetic tape that make any of the thousands of individual designs instantaneously available."[5]

It is clear that Gilmore, Taylor and Fitzgerald had a good grasp of what this type of technology was capable of. One problem was that a system as described above had a price tag of nearly $500,000. That was a lot of money in 1962.

**Itek sells EDM technology to Control Data**

In late 1962 it became clear to Itek that as a defense contractor, it would have a hard time commercializing the EDM. Taylor negotiated a deal with Control Data Corporation to acquire the EDM technology and related patents from ITEK.[6] Prior to that occurring, Itek did sell one system to Walker at AFCRL. This installation was referred to as the DX-1 system and the software as the Digigraphics Display Program. The general configuration was similar to the prototype EDM except that the Telex disk was replaced by a Bryant magnetic drum memory. Two foot pedals were also added for additional operator interaction. The display data stored on the drum used six-bit bytes as compared to the four-bit bytes used on the EDM prototype. This enabled the DX-1 to display approximately 2,000 linear inches of drawing as compared to about 800 inches on the earlier EDM.

The Digigraphics software was similar to what had been implemented on the EDM but with some important extensions. In particular, it was now much easier to display any selected area of a drawing at a wide variety of scales. The DX-1 system included an interface to a second PDP-1 computer that was equipped with a color display. The Digigraphics software project leader for Adams Associates was David Eisenberg and his Digital counterpart was Ed DeCastro who went on to start Data General a few years later.

After CDC acquired the EDM technology from Itek, it established a new business entity nearby called the CDC Digigraphics Division. Adams Associates was hired to convert the Digital PDP-1 software to the substantially more powerful CDC 3200 computer system. One of the key CDC employees involved in this activity was Thurber Moffett. The company developed its own Digigraphics workstation, the CDC 274

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[5] Leland, Timothy, "Computer Language Barrier Broken," *The Boston Sunday Herald*, December 30, 1962, Pg. 46

[6] Taylor subsequently worked for CDC as a technical assistant to Chuck Norris, the company's CEO, until the late 1960s. He then was a consultant at Arthur D. Little and at his own firm, Corporate Tech Planning until he retired in the late 1980s.

 

Graphics Console, that could display 2,000 linear inches of graphics or 1,800 text characters.

CDC struggled to make this technology commercially viable, but it was wine before its time. The functionality was less than what was needed to do most real-world design and drafting tasks and the use of stroke refresh graphics resulted in systems that were far too expensive. Several systems were sold to aerospace companies including Lockheed and Martin Marietta (subsequently merged into what is today Lockheed Martin).

The company also received several research contracts from the United States Navy to work on submarine design problems, especially those involving shipboard piping. The Navy wanted to be able to take a slice through a submarine and see if all the ducts, pipes and tubing would fit. One problem with the aerospace customers was that while CDC was still trying to perfect computer-aided drafting, they wanted to focus on basic design.

Several systems were also sold to semiconductor manufacturers since they could work with the simple graphics the Digigraphics systems were capable of producing. Within several years, CDC concluded that this business was unprofitable and closed up the Digigraphics operation.[7]

Perhaps the best description of the EDM's significance was Jack Gilmore's observation in 1990: "…the point I'm making is that we had to wait almost 15 years for the hardware to catch up with us so that we had a reasonable workstation that we could put some of this hotshot graphics in."[8]

In the mid 1960s, the EDM and Digigraphics work resulted in Adams Associates (subsequently known as Keydata Corporation) being hired by Largo Oil and Transport ( a subsidiary in Aruba of what is now ExxonMobile) to implement a graphics based oil refinery movement and control system. An operator could point to a series of tanks, valves, pumps and pipelines with a light pen and tell the system to move a specified amount of material from one group of tanks to another group using the selected routing. I spent the better part of four years managing the software aspects of this project which involved display systems provided by Information Displays Incorporated, a company Carl Machover was executive vice-president of at the time.

Jack Gilmore became president of Keydata in the late 1960s and ran that company for several years before going to work for Digital in 1974 where he was instrumental in that company's office automation business activities until he retired. Itek Corporation was eventually sold to Litton Industries Incorporated and then acquired by Hughes Electronics Corporation in 1997. It is interesting to note that in the late 1960s two significant CAD vendors discussed in depth in this book were established just a few miles from where Digigraphics had been located - Applicon and Computervision.

[7] CDC records available at Charles Babbage Institute, University of Minnesota, Minneapolis.
[8] Panel discussion held at Digital Equipment Corporation on June 5, 1990

# Chapter 7

# Applicon

Applicon was founded in 1969 as Analytics, Inc. in Burlington, Massachusetts by a group of programmers from MIT's Lincoln Laboratory where they had been working on advanced interactive graphics technology. The four principals, all of whom had Ph.D.s, were Gary Hornbuckle, Fontaine Richardson, Richard Spann and Harry Lee. Their work at Lincoln Lab included the development of a technique for command entry that involved sketching a pattern on a tablet with a stylus. Tablet pattern recognition for command entry would become one of the defining characteristics of the company's products throughout its life time.

According to Richardson,[1] the founders frequently had lunch together at Lincoln Lab and often discussed Wall Street's infatuation with technology startups. Many people forget that the late 1960s saw a high-tech boom similar to, although smaller, than what we would see repeated several times over the next three decades. One of the group's models was Digital Equipment Corporation which had been started by Lincoln Lab engineers in 1957 and by 1969 was a major player in the computer industry. Professor Edward Roberts of MIT's Sloan School did a study of startups, including those started by former Lincoln Lab employees. He presented his findings during a lecture at the Lab with a statement that 80 percent of the earlier startups were still viable five years later. This was like throwing gasoline on a fire and the four became determined to start a company.

The casual lunches turned into evening and weekend meetings with the conclusion that they should start a company that focused on their personal expertise and experience – software for designing electronics. After substantial discussion, Hornbuckle became the company's president, Lee the chairman of the board, Spann the vice president of sales and marketing, and Richardson the vice president of product development. In reality, all the founders had a hand in developing the company's early products.

Initial funding was provided by W. R. Grace and Company which arranged for an initial bank loan and subsequently purchased one sixth of the company for $400,000 in late 1969. General Electric invested in the company in 1972 and 1973 at the encouragement of early Applicon users within the company. Eventually, GE's investment would represent a nearly 28 percent ownership of Applicon prior to the company's initial public offering. J. H. Whitney, a venture capital firm that would later play a major role in Computervision's demise, invested in 1974. Shortly after the company's founding, they were informed that the name "Analytics" was already being used by another company. Applicon was a made up name that was a contraction of the word "application."

The Computer Science Department at the University of Illinois at Urbana-Champaign has a short biography of Richardson on its web site. In 1968 he was the second person to receive a Ph.D. in computer science from that institution. According to this web site, Applicon's plan was to develop a suite of four products. "One was for designing integrated circuit photomasks, one was for digital circuit simulation, one was for frequency domain circuit synthesis, and one for microwave circuit analysis." Except

[1] Richardson, Fontaine, email to author dated February 8, 2004

 

for the mask layout program which required a stand-alone computer system, the software was intended to be sold on a timesharing basis. When a recession hit in 1969-1970, potential customers found it difficult to purchase software on an as-used expense basis. Applicon dropped the timesharing software and focused on the integrated circuit mask layout system which could be sold as capitalized equipment. This product soon became known as the "Design Assistant." The company's first customer was Matsushita in Japan.[2]

The company's initial interactive graphics solutions for designing printed circuit boards and integrated circuits used IBM's 1130 computer with terminals consisting a storage tube display, keyboard and tablet. The terminals were designed and built by Computek, another MIT spin-off based in Cambridge, Massachusetts. The IBM 1130 was selected because it could be rented as well as sold, a financing issue the Applicon founders thought would help in some sales situations. About eight or ten of these systems were sold. Shortly thereafter, Applicon switched to Digital Equipment Corporation's new PDP-11 and the company worked almost exclusively with Digital until well into the 1990s.

**Applicon System Almost Goes Up in Smoke**

*The following story was related to the author by Fontaine Richardson*[3]

In the early days, we had to deliver the system and get the installers to the site to make the installation and conduct the training. The customers paid the freight to transport the system, so, the obvious choice was to rent a truck, drive the system to the site, install the system and train the customers before driving home.

Our first DA 700 system (The PDP-11 version of the product) was purchased by GE for Waynesboro, Virginia. It was delivered in late August 1971. Jim, the field service technician and I loaded the system in the back of the rental truck about 6:00 PM on a Sunday evening in Burlington, Massachusetts and drove south, intending to drive all the way through the night and deliver the system the first thing Monday morning. We got as far as Philadelphia when, in a driving rain, neither one of us could stay awake at 2:00 AM. We decided to find a hotel and get some sleep and go on the next morning. Jim was driving. I told him to drive under the hotel awning so I would not get wet when I went in to inquire if there were rooms available.

The truck was taller than the awning and we hit it at about 5 miles per hour. This got the hotel's night clerk's attention. Despite this rude arrival, he did have a room for us. We parked the truck and started toward the hotel. I happened to look back at the truck and noticed an unusual amount of steam rising from the hood of the truck. This struck me as unusual and I went back to check on what was going on. I put my hand on the truck's

[2] Computer Science Department at the University of Illinois at Urbana-Champaign web site - http://www.cs.uiuc.edu/news/alumni/sp95/richardson.html
[3] Richardson, Fontaine, email to author dated February 8, 2004

 

hood and it burned my hand. I didn't think that this was typical. I looked into the front grill of the truck and saw flames. Always the person to avoid the risky work, I told Jim to stay at the truck and get the hood opened.

I ran to hotel to call the fire department and see if I could find a fire extinguisher. I awakened the hotel clerk again and asked him to call the fire department. I ran through the hotel until I found a soda acid type fire extinguisher and ran out to the truck. Jim had not been able to get the hood open and was of the opinion that a truck explosion was imminent. Our first and only system was in the back of the truck and I knew that I would have a difficult time explaining to the customer and the folks back home that I had let the system perish in a fire.

I turned the fire extinguisher upside down to activate it and pointed the hose through the grill of the truck at the base of the fire. I was able to put out the fire in what seemed like an eternity.

In the morning, we determined that there was a black scorch mark on the hood of the truck that had not been there when we left Burlington, so we hadn't dreamed the fire. We looked under the hood and discovered that the gas line was loose and was dropping gas onto the hot engine manifold. This was less of a problem at highway speed, but flared up after the truck was parked.

We drove on to Waynesboro without further distraction. The scorched truck hood gave our story some credibility, although our customer was still skeptical.

Early marketing into the electronics industry tended to focus on the conceptual design departments of the target companies. This differed sharply from competitors such as Calma and Computervision which focused more on the production drafting groups at these companies. Sales grew from about $500,000 in 1971, to over $9 million in fiscal 1975 (company's fiscal year ended on April 30th) and to over $18 million in 1978. A major financial bump in the road occurred in 1978 when sales stagnated and the company incurred a $700,000 loss.

Two key members of the company's board of directors, Alex Daignault of W. R. Grace and Don Ackerman of J.H. Whitney, believed that the company was struggling to generate sales and needed a new product strategy if it were to be competitive in the future. They explored the possibility of the company being acquired but there were no acceptable offers. The other option was to bring in a new management team. Don Feddersen, who was recruited by Ackerman, had been president of Entrex, a vendor of educational software, until it was acquired by Nixdorf. Feddersen had also been general manager of Gould's Data Systems Division. He became president and CEO of the company on April 19, 1978.

As a result of this management change, Applicon went from being a technology driven company to more of a business driven enterprise. Its primary competitors at the time were Computervision and Calma and to a lesser extent, Auto-trol Technology and M&S Computing (Intergraph). Feddersen controlled expenses fairly tightly – perhaps too tightly. One project he curtailed was the development of a stand-alone workstation using a TI-9900 microprocessor and raster graphics. Started in 1977, it would have been one of the first workstation products in the CAD industry.[4]

Hornbuckle left Applicon later that year. Lee had left the company fairly early and Spann, who had taken on the responsibility for advanced development and engineering, had left in 1976. Richardson, the last of the founders, stayed the longest, until shortly after the company went public in 1980. Hornbuckle founded a new graphics company, Impress, Inc., in 1980. Impress developed a system capable of scanning and editing engineering drawings, primarily for technical illustration. Around the same time, Spann joined Adage, a manufacturer of computer graphics terminals, as vice president of operations. He became CEO of Adage in 1978 and held this position until 1988. Both Spann and Richardson ended up in the venture capital industry. Spann founded PreFund Associates while Richardson was a long-time general partner at Eastech.

**Description of early Applicon systems**

During the 1970s and early 1980s Applicon's products used the AGS nomenclature. AGS stood for Applicon Graphics System. The typical Digital PDP-11 system supported up to four terminals.

The key characteristic of Applicon's AGS software was its pattern recognition command entry or what the company called Tablet Symbol Recognition. As an example, if the user wanted to zoom in on a specific area of a drawing, he would simply draw a circle around the area of interest with his tablet stylus and the system would regenerate the image displaying just the area of interest. A horizontal dimension was inserted by entering a dot followed by a dash while a vertical dimension line was a dot followed by a short vertical line. The underlying software was command driven and these tablet patterns simply initiated a sequence of commands. The system came with a number of predefined tablet patterns but users could create patterns to represent any specialized sequence of operations desired.

The initial AGS software was written in assembly language and for the most part, Applicon did not use a Digital provided operating system for its PDP-11 systems. This changed around 1978 when the company moved to the RSX-11M real time operating system and programming was increasingly done in FORTRAN. Also in 1978, Applicon introduced its first raster display terminal as an alternative to the storage tube. These early units had relatively poor resolution compared to storage tube terminals but they did not require images to be fully redrawn whenever something was moved or deleted. Shortly thereafter, Applicon was one of the first CAD companies to offer color raster terminals which added a new dimension to the visualization of design and analysis images.

The key system component at this time was a Digital PDP-11/34 minicomputer. Applicon repackaged this computer in its own cabinet along with its Graphics 32 processor and referred to the combined system as the AGS/895 Central Processing Facility. In addition to 208KB of main memory, the AGS/895 included a 200MB disk drive (expandable to 800MB) and a dual density (800/1600 bpi) magnetic tape drive. The Graphics 32 had its own 64KB memory and performed vector to raster conversion and patterned area filling for up to four terminals. The AGS/895 was capable of supporting four terminals plus four background tasks such as PCB routing. In the 1980 time period,

[4] Personal email from Walter Anderson, August 18, 2006

 

Applicon offered ten different storage tube and color raster terminals for use with the AGS/895. (Applicon's marketing department also used the "Image" nomenclature to describe these systems.) A typical system, probably with two or three terminals, sold for $300,000.

The basic system the company offered was called the AGS/900 Multi-Tasking Operating System which incorporated the AGS/895 Central Processing Facility running Digital's RSX-11M operating system. The AGS/900 was the software framework for the company's Interactive Multi-Activity Graphics Environment or IMAGE which enabled a single system to run both two-dimensional and three-dimensional software at the same

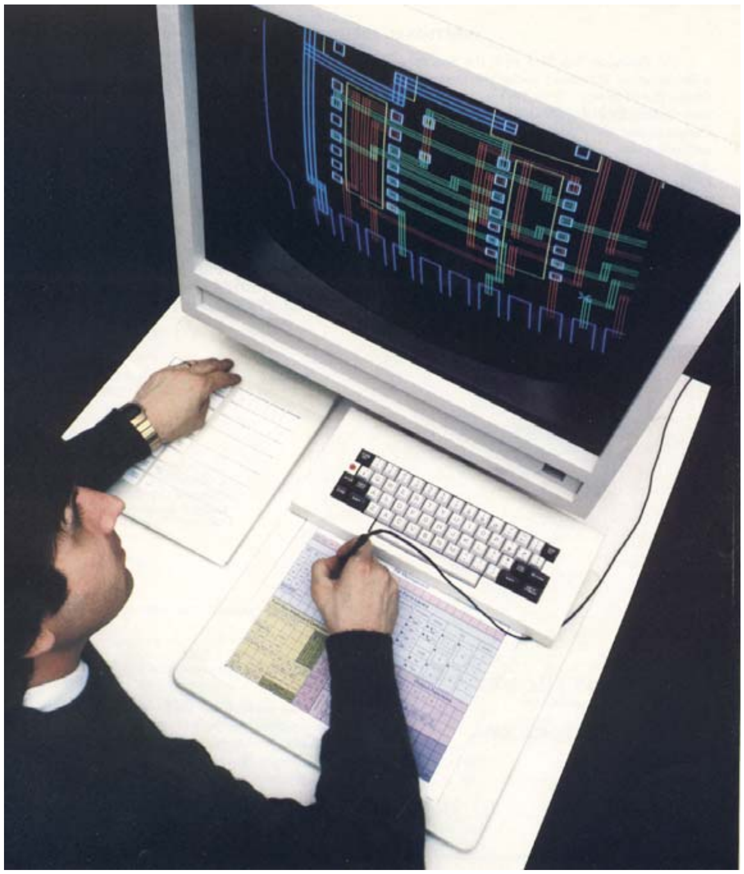

Figure 7.1
Typical Applicon Color Raster Workstation With Tablet, Keyboard and Function Panel[5]

time. The specific application-oriented products were called the AGS/870-I two dimensional and the AGS/880-I three-dimensional systems. The AGS/870-I was targeted at electrical design tasks, particularly the schematic and physical design of printed circuit boards while the AGS/880-I was intended for mechanical design and drafting. Numerous task-specific applications modules were available for these systems including PCB placement and routing, wire list generation, photoplotter output, bill of material generation, nesting and flame cutting flat pattern development and numerical control. The first mechanical system was sold to General Motors.

[5] *Applicon Preliminary Prospectus*, June 18, 1980

In addition to the AGS/900 systems, Applicon also offered the AGS/860 VLSI Graphics Application System which incorporated two-dimensional software tailored for the design and editing of VLSI circuit masks. It used the same interactive techniques of other Applicon systems plus a number of optional output packages specifically implemented to support VLSI artwork generation. The AGS/860 utilized the same AGS/895 Central Processing Facility as did the AGS/900 systems except that it supported a more limited number of terminals.

Figure 7.2
Applicon Graphic System[6]

A key software component of the AGS/860 was the AGS/1610 Designer/MOS interactive design package. It provided a set of tools for designing and editing integrated circuits that took advantage of Applicon's color graphics technology. Other specialized AGS/860 software included a Design Rule Check Package (AGS/862) which was used to verify the geometric layout of VLSI designs prior to producing specialized output. There were also output packages to support CalComp, Xynetics, Versatec and Applicon plotters as well as Mann and Electromask optical pattern generators. At the time, this was one of the leading integrated circuit design systems on the market, along with similar products offered by Calma and Computervision. Within a few years it would be overshadowed by a new generation of systems from companies such as Daisy and Mentor Graphics which

[6] *Applicon Preliminary Prospectus*, June 18, 1980

introduced new design procedures that relied on logical definitions of circuits rather than pure graphics representations.

By 1981, over 90 percent of the company's terminal shipments were raster devices, many of them color units. Applicon developed its own graphics processor – a 32-bit bit-sliced microcomputer system – that handled graphic tasks independently of the system's central processor.

Like most other turnkey system vendors of that era, Applicon was interested in manufacturing as large a portion of the systems it sold as was feasible. This led Applicon to design and manufacture the industry's first continuous ink jet color image plotter in 1977. The company had been approached by Walter Carnes from Arthur D. Little, a management consulting firm in Cambridge, concerning "Drop on Demand" ink jet technology that had been developed in Sweden by Helmut Hertz, the grandson of Heinrich Hertz, the German physicist who gave his name to our current measure of electronic frequency. ADL was looking for a licensee to manufacture and market a color plotter using this technology and Applicon was receptive to the offer. The expectation was that it could be sold to the company's customers to produce plots of integrated circuits and maps.

The Applicon color plotter used three specially formulated inks (magenta, yellow and cyan) to produce plots with a resolution of 300 dots per inch. The paper ( up to 36-inches by 48-inches) was held on a rotating drum and the print head was moved laterally from one end of the drum to the other with a stepper motor controlled lead screw. The rotation speed of the drum was user controlled and at its fastest speed it was capable of generating a 22-inch by 34-inch plot in as little as 8.5 minutes although high quality plots could take as much as five times as long to produce.

Figure 7.3
Applicon Color Ink Jet Plotter

The plotter was not an on-line device but was controlled from a magnetic tape drive. Part of the system was Applicon's COLOR software system, also licensed from a Swedish developer, which converted traditional vector and spatial data into the raster format required for plotting and placed that data on magnetic tape. The software could produce over 5,000 different color shades. The company promoted the color plotter for mapping, seismic data analysis, printed circuit board design and graphic arts applications but not as a mechanical design tool. It made up about six percent of the company's revenue in 1980.

In the late 1970s Applicon established co-operative development and marketing agreements with several other companies. One of these was with Structural Dynamics Research Corporation (SDRC) that facilitated the integration of Applicon's mechanical design software with SDRC's Computer-Aided Engineering (CAE) software. See Chapter 17. This integration only worked on Digital PDP-11 systems running RSX-11/M software. A second agreement was with University Computing Company (UCC) which had developed its own APT software for programming machine tools called UCC-APT. In this environment, Applicon users could design parts and produce NC machining instructions and then use that information to generate either an APT source file or an APT CL (Cutter Line) file. This data was then processed by UCC's APT software and library of post-processors to produce a control tape for a specific machine tool.

Even with the limited functionality of 1980 era Applicon software and the hardware performance limitations at the time, users were seeing significant productivity improvements. Customers such as Hughes Tool, Houston, Texas, were publicly stating that new designs were being completed in half the time as before.[7] Productivity was a big issue in 1980, particularly in the United States. The country was experiencing record inflation at the same time that the growth in productivity was unusually low. At the time, not many people linked the two issues together. Twenty years later, the country would experience very low inflation and high growth of productivity, a significant portion of which was due to the explosive use of CAD/CAM technology.

**Public offering then Schlumberger acquisition**

Feddersen came on board in April 1978 and by early 1980 he had Applicon back on track. Revenue for the year ending April 30, 1980 was up 78 percent to $50.8 million from the prior year and earnings were up nearly five-fold to $3.1 million. While the company's strongest market segment was the electronics area, it clearly recognized that the greatest potential was for mechanical CAD systems.[8] Revenue and earnings for fiscal years ending April 30th were:

| Fiscal Year | Revenue | Earnings |
|---|---:|---:|
| 1974 | $7,300,000 | $300,000 |
| 1975 | 9,500,000 | 100,000 |
| 1976 | 10,183,000 | $31,000 |
| 1977 | 16,640,000 | 789,000 |
| 1978 | 18,372,000 | (717,000) |
| 1979 | 28,469,000 | 671,000 |
| 1980 | 50,776,000 | 3,149,000 |

[7] Lerro, Joesph P., *Design News*, November 17, 1980
[8] *Applicon Preliminary Prospectus*, June 18, 1980, Pg. 16

 

By 1980 there were over 500 Applicon systems in use, the staff had increased to 785 people and the company was building a 120,000 square foot manufacturing plant. This appeared to be an excellent time to go public and the company did so on July 22, 1980 by selling 1,045,000 shares at $22 per share. At the same time, investors who owned preferred shares and warrants converted their shares into common stock. Nearly a quarter of the money raised went to pay off bank loans the company had incurred to finance its rapid growth during the prior two years while the balance went to finance future expansion.

Key personnel as of mid-1980 were:

Donald Feddersen – President and CEO
Don Ackerman – Chairman of the board
David Barber – Vice president of marketing
Steven Cheheyl – Vice president of finance and treasurer
Richard Diephuis – Vice president of system development
Thomas Genova – Vice president of engineering
Robert McCormick – Vice president of international marketing
William Mason – Vice president of operations
Albert Moulton – Vice president of program product development
James Nitz – Vice president of sales
Fontaine Richardson – Vice president of industry marketing

Prior to Applicon's public offering, General Electric offered to buy the 72 percent of the company that it did not already own for $20 per share, or approximately $66 million.[9] When this offer was rejected, GE went shopping for another CAD/CAM vendor and eventually acquired Calma. GE, under pressure from the Federal Trade Commission, then sold its Applicon stock in mid-1981 in a secondary offering. At the same time, Applicon sold another 260,000 shares of stock at $33 per share. In mid-1981 Richardson left Applicon to become an independent consultant and visiting scientist at MIT.

When Applicon went public, about 20 percent of its revenue was from international customers. Half of this business was from Europe while Japan and the rest of the world made up the balance. Domestically, the company had 23 sales offices split into five sales regions as well as sales offices in six European countries. Applicon's distributor in Japan was Marubeni Electronics. Overall, there were 192 people engaged in marketing, sales and sales support worldwide.

On September 7, 1981, Applicon shocked most industry observers when it announced that the company was being acquired by Schlumberger in a stock deal valued at approximately $232 million. Schlumberger was a French controlled company, chartered in the Netherlands Antilles and headquartered in New York. It was then and still is today a major supplier of various services to oil and natural gas producers. It also owned Fairchild Semiconductor and earlier in 1981had acquired MDSI, a vendor of numerical control software. With the acquisition of Applicon, MDSI withdrew its low cost COMPDRAW IV turnkey system from the market and reduced development work on solids modeling, leaving these areas to Applicon. The two companies became the core of what Schlumberger called its Computer-Aided Systems Group. Eventually Schlumberger would merge Applicon with MDSI and move the combined company's

[9] *Applicon Preliminary Prospectus*, June 18, 1980, Pg. 24

 

headquarters to Ann Arbor, Michigan where MDSI was located, but that didn't happen for several years. Initially, there was very little cooperation between Applicon and MDSI. Each company went its own way and that fit in with Schlumberger's style of highly decentralized management.

In an attempt to broaden its mechanical product line, Applicon had earlier signed the previously mentioned development and marketing agreement with SDRC. Under this agreement Applicon was reselling SDRC's Supertab finite element modeling software and SDRC had set up half a dozen automated design service centers in the United States and Europe that were equipped with Applicon systems. Customers could rent these systems for $50 per workstation hour or hire SDRC designers and drafters to do the work for them. By early 1982, the working relationship between the two companies had become somewhat strained. At the same time, a group of SDRC managers were considering establishing their own company to develop and market CAE software. This group consisted of Dick Miller, Rex Smith, Paul Vollbracht and Vic Nicolas as well as Jim Brown who was with General Electric, an SDRC business partner as discussed in Chapter 17.

The group approached Feddersen with an offer to develop CAE software for Applicon. Eventually, Jason (Jack) Lemon, the CEO of SDRC, found out that Smith was involved in this endeavor and accused him of planning to leave the company. Smith relayed that information to the other individuals who then contacted Feddersen to see if he was the one who had told Lemon. Feddersen's response was an offer to hire the group as Applicon employees and set up an office for them near Cincinnati. Shortly after hiring this group in the spring of 1982, Feddersen also hired Russ Henke, SDRC's then president and COO. Henke's job at Applicon was to head up the company's mechanical activities. After Henke came on board he asked Miller to move to Boston and become marketing manager for the mechanical group and Smith to take over software development. Smith basically commuted to Boston rather than relocating.

**Introduction of solids modeling software**

In June 1981, Applicon made its first move into solids modeling by licensing a software package called Synthavision from MAGI (Mathematical Applications Group, Incorporated) located in Elmsford, New York. The software, called simply Solids Modeling by Applicon, ran on Digital's VAX 11/780 and 11/750 systems. The actual implementation was somewhat awkward, however. The user created a wireframe three-dimensional model on Applicon's PDP-11 AGS system and then transferred the data to the VAX computer where Synthavision created a solids model based upon the transferred data using 14 different primitive shapes, an operation that typically took several minutes. The model could then be viewed on a color terminal attached to the VAX. The data transfer was via DECnet, which was by now a standard Applicon product, or on magnetic tape.

Once the model was generated in Synthavision, the user could cut cross sections through it to reveal internal components as well as calculate mass properties such as weight, volume and center of gravity. The user could also define which views should be converted to drawings. That data was then returned to the AGS system as wireframe images with hidden lines removed or shown as dashed lines in order to produce typical engineering drawings. Changes to the model could not be made on the VAX system, however. The user had to make those changes using the AGS software and then regenerate the changed model on the VAX. In general, the intent was not to design interactively with solids but to use the technology to enhance analysis, visualization, and interference detection.

This software was first shown at the 1981 NCGA Conference in Baltimore, MD. According to *The Anderson Report*, "The demos Applicon ran at the NCGA Conference in Baltimore were real show stoppers."[10] Applicon was the first turnkey CAD system vendor to offer solids modeling as a standard package. It was fairly expensive at $50,000 per copy and needed a VAX computer in addition to the PDP-11 running the AGS system. The company took the interesting step of trade marking the term "Solids Modeling." As far as can be told, this latter action either never held up in court or the company did not attempt to enforce the trademark.

At the same time Applicon introduced its first solids modeling package, it also introduced a new PCB routing and placement package designed to run on VAX 11/750 and 11/780 computers. The primary result of moving this software to the VAX was to achieve improved performance over the PDP-11/34s currently being used to run the company's software. Applicon claimed a 50 to 400 percent improvement in routing and placement speed. Interactive creation of schematics was still done on the PDP-11 using the company's Video PCB System software. Net lists were then extracted from that database and transferred to the VAX via DECnet or on magnetic tape much like the way the solids package worked. The placement software provided the user with the choice between automatically placing components or doing it interactively. The routing software was priced at $40,000 while the placement software was $10,000.

In November 1981 Applicon announced a new PCB packaging and placement program that supplemented the software announced in June. A month later the company introduced a new package called Designer Logic which automated many tasks related to the creation of integrated circuit schematics and the extraction of data needed to run logic simulators.

Also in November 1981, Applicon introduced new technical documentation software. In reality, this software did not address the drawing tasks of professional illustrators as did similar software offered by Auto-trol Technology. What it did do was enable a user to merge text and graphics and then output page images to either an Autologic APS-5 Digital CRT Phototypesetter or a Xerox 9700 Electronic Printing System. These software interfaces sold for $17,500 each.

Applicon also had a moderate presence in the AEC sector of the CAD industry and offered software for applications such as process plant piping design. An internal Applicon document written in November 1982 by Kevin Cavenaugh in the company's international marketing department described a competitive benchmark against Intergraph that the company participated in for a European chemical company. In addition to using Applicon's Piping Design package to do traditional plant design, two application engineers spent a week building a solids model of the plant. This model showed that there were several critical flaws in the prospect's proposed design including a pipe running through two large girders and a stairway running through another major pipe. Supposedly, the company was sufficiently impressed that it planned to purchase an Applicon system rather than Intergraph even though the latter was installed at another

[10] *The Anderson Report*, July 1981, pg. 1

 

company site. We don't know if this ever came to pass since the prospect was not identified in the memo. In general, Applicon never became a major factor in the AEC market space.

**The VAX era begins**

Applicon had been deeply committed to using Digital computers since shortly after it started developing CAD systems. When the VAX 11/780 was introduced, the company's technical and marketing people certainly saw this as a logical extension of the AGS product line. At $250,000 per unit, the 11/780 was pricey for the company's customers. When Digital announced the future availability of the lower cost VAX 11/750, that changed the equation and the company began to seriously work towards adding the machine to its suite of products. With the VAX introduction on the horizon, Applicon shied away from adding more powerful PDP-11 machines such as the PDP-11/70 to the company's product line. At AUTOFACT in Detroit in November 1981, Applicon let the media know that implementation of a VAX-based system was running more than a year behind schedule. At the same trade show, the company showed a glimpse of its new raster workstation behind smoky glass panels.[11]

The company restructured its computer product line in April 1982 when it announced the 4000 Series. It started with the 4225 Graphics Processing Facility which consisted of a PDP 11/34 system, an 80MB disk drive, one monochromatic workstation, a 32-bit graphics display processor and basic application software priced just under $100,000. The 4245 added a 300MB disk and a magnetic tape unit with prices starting at $160,000. The top of the line 4275 was based on a VAX 11/751 computer which the company claimed would support up to 12 terminals compared to the four the PDP-11/34 supported. The VAX-based 4275 apparently ran most of the 16-bit PDP-11 code in emulation mode although some early 32-bit beta code may have been included with this product announcement.

According to *CAD/CAM Alert*, Applicon's sales force did a particularly good job of keeping a lid on the introduction of the 4275 since premature marketing of this unit would have frozen sales of the company's existing PDP-11 products.[12] (For anyone confused by the 11/751 nomenclature, this was the OEM version of the VAX 11/750. As far as I can tell there were no differences other than the model number.) Applicon's statement that the VAX 11/751-based 4275 could support 12 terminals was overly optimistic and a reasonable configuration would eventually prove to be more like two to four unless the users were simply doing very basic drafting tasks.

The company also added SEED, a commercial database management package, to its product line as well as a user programming language. A communications protocol called DGN for Distributed Graphics Network supported communications between the VAX and PDP-11 computers. With a VAX computer in the product line, users of Applicon's solids modeling software could now run it on the same computer although the need to translate data between Synthavision and the company's CAD software still remained.

[11] *CAD/CAM Alert*, December 1981, pg. 6
[12] *CAD/CAM Alert*, May 1982, pg. 2

At the same time, Applicon introduced a new color raster workstation with 768 by 576 resolution and optional hardware anti-aliasing.[13] The latter technique smoothed out non-orthogonal lines and made them look less jagged. This was a major problem with early raster display terminals and one of the reasons that a number of vendors still offered storage tube terminals. The anti-aliasing option was called PERL for Perception Enhanced Resolution Logic. The color version of this terminal sold for $70,000 while the monochromatic unit was $40,000.

**The state of Applicon in mid-1983**

As Applicon prepared to introduce a new generation of mechanical design software, it is probably worthwhile to review where the company stood technically and business-wise in mid-1983. The company advertised the fact that it was in three market segments; electronic design of PCBs and integrated circuits, mechanical design and AEC. As mentioned earlier, it was not a major factor in the AEC space as compared to Intergraph, Auto-trol, Calma and Computervision and there is little evidence that the company was planning to put significant resources into developing new architecture and civil engineering software. Likewise, it was obvious that its interests were switching from electronics design where it had been a major factor for a number of years to the mechanical market which was perceived by many to be where the most significant future growth would occur.

The company's business model was predicated upon building a significant portion of the systems it sold. VAX and PDP-11 computers were purchased from Digital and resold to customers although the company did not sell the larger VAX 11/780, only the mid-range 11/751. Terminals were a major source of revenue and were predominately manufactured in-house. By this time, virtually all the units being shipped were raster units, many of which were color and included the company's proprietary 32-bit graphics processor. Other than software, this was probably the most profitable part of Applicon's business. By 1983, it appears that the company was no longer producing the color ink jet plotter it had launched in 1977 and was reselling plotters from companies such as CalComp. Most of the company's products were produced in a 170,000 square foot manufacturing plant in Billerica, Massachusetts.

The company sold its products through a direct sales force with more than 30 sales offices. Regional headquarters were located in Chicago, Philadelphia, Dallas and Santa Clara. European headquarters were in Paris, France along with sales offices in Germany and England. Other parts of the world such as Australia and Japan were handled by distributors. By this point in time, the company had an installed base of 1,500 systems supporting over 3,000 interactive workstations. Two workstations per system was a much lower ratio than what one found with most competitive systems. At this point in time, Applicon offered several hundred specialized application packages. Since the company used standard Digital computers, the entire library of third party software packages available for those machines were also available to Applicon's users.

Key personnel included:

- Don Feddersen – President and CEO
- Russ Henke – Vice President –effectively second in command

[13] *CAD/CAM Alert*, May 1982, pg. 2

- Dr. Jack Horgan – Director of planning and technology
- Dick Miller – Director of marketing
- Rex Smith – Director, Ohio Development Center
- James Kotanchik – Director of systems software
- Richard Tarulli – Vice president, U.S. sales

**A new generation of software**

In 1981, Applicon began development of what would eventually prove to be its most important software product, BRAVO!. At the time, it was expected to be an 18 month project – it ended up taking 42 months and $22 million in R&D funds when it was formally announced on June 28,1983. The software was written in PL/1 for Digital's VAX product line, including the 11/730, 11/751 and 11/780. This was new software, not simply the PDP-11 version of the company's CAD/CAM software converted to run on the VAX. At the same time, Applicon offered its CAD/CAM software unbundled for customers who purchased VAX 11/780 computers directly from Digital. The launch of BRAVO! did much to re-energized the company which in 1983 was loosing market share at an alarming rate. Unfortunately, the software was released a number of months before it was ready for prime time and early users struggled with some of its functionality..

BRAVO! included a new database manager, a new user interface with on-screen menus, an integrated interactive solids modeler (Solids Modeling II) and mechanical engineering tools. The interactive two-dimensional and three-dimensional design and drafting module retained the Applicon Editor nomenclature as well as the Tablet Symbol Recognition capability of earlier software. Finite element modeling and analysis was available as an option. The solids modeler supposedly responded to most input commands in five seconds or less, but was able to do so only by using limited colors. When the user wanted to see a realistic rendering of the model, that could be done but it took more time. BRAVO! also included a new user programming toolkit called the AGL (Applicon Graphics Language) Programming Package.

Applicon's initial solids modeling package described earlier generated solid models in a batch mode on a VAX computer using wireframe models created on the AGS' PDP-11/34 computer. This was good for visualizing models and calculating mass properties but was not an interactive design tool. Solids Modeling II, on the other hand, was a true interactive solids modeling program. Users were able to build models of individual parts and assemblies using geometric primitives such as spheres, cubes, cones and even objects incorporating free-form surfaces and surfaces of revolution. Once a model was completed, wireframe images with hidden lines removed could be extracted from the model and used to produce engineering drawings. Changes made to those drawings could not be used to change the solid model – it was a one way path.

While most users probably had a difficult time adapting to the concept of solid modeling, Applicon's Surface Modeling Package was more immediately useful to the typical BRAVO! customer. This surface modeling software was more tightly integrated with traditional wireframe design than was the solids package. Users could create surfaces ranging from simple spheres, cones and cylinders to surfaces of revolution and warped B-spline surfaces. Models built with these surfaces could be used by other applications such as finite element modeling and NC part programming. This process was not as fully automatic as the sales literature would have one believe and there continued to be a substantial amount of data re-entry.

Model data could also be used by the Applicon Editor to produce drawings. Productivity improvements when drafting cross sections were said to be particularly impressive. Prior to the eventual merger with MDSI, Applicon was never a major factor in the high-end NC market space. Dick Miller remembers a major effort to develop a five-axis machining capability for a Martin-Marietta customer site only to find out that this facility had no five-axis machine tools and that the requirement was for a “future possibility.”

The Database Manager was designed to handle all graphic and attribute information with individual applications accessing whatever data was needed. The intent was to eliminate all translation of either graphics or attribute data between applications. With Solids Modeling II and the new Surface Modeling Package, Applicon had one of the industry’s first hybrid modeling capabilities where users could work in a combination of wireframe, solids and surface geometry. The company also announced pre and postprocessors for IGES, the Initial Graphics Exchange Standard, which was quickly becoming a system prerequisite for most large user organizations.

This new software was offered only on the VAX platform meaning that existing customers had to replace their PDP-11 systems if they wanted to use BRAVO!. Applicon sold complete turnkey VAX 11/730 and 11/751 systems with prices starting under $120,000 for a single workstation 11/730 system. This did not include either the Solids Modeling II or Surface Modeling packages. If a customer wanted to use a VAX 11/780, that system had to be purchased directly from Digital and the software and workstations from Applicon. This semi-unbundled model did not include the ability to use non-Applicon terminals to utilize the Applicon software. Prices for many packages varied based upon the size of the VAX computer being used. As an example, the AGL Programming Package cost $10,000 for the 11/730, $20,000 for the 11/751 and $30,000 for the 11/780. This 1-2-3 pricing ratio was also used for other BRAVO! modules.

In addition to Solids Modeling II and Surface Modeling, the company introduced three additional mechanical engineering packages; GRAFEM (Graphic Finite Element Modeling), IFAD (Integrated Finite Element Analysis and Design) and Mechanisms. GRAFEM was a finite element analysis pre and post-processor that facilitated creating viewing and editing finite element models and viewing analysis results. IFAD used the models created by GRAFEM for linear static and dynamic analysis. Both of these were developed internally by Applicon. The Mechanisms package calculated static equilibrium and time response data for two and three-dimensional rigid body mechanical systems. It used software licensed from Mechanical Dynamics Incorporated (MDI). While IFAD provided a basic analysis capability some users apparently wanted more comprehensive finite element analysis software. To meet this need, Applicon signed a marketing agreement with MacNeal-Schwendler Corporation to license that company’s MSC/NASTRAN software for use on BRAVO! VAX-based systems. GRAFEM could still be used for pre and post-processing in this latter situation.

These were not inexpensive packages. For the VAX 11/780 Solids Modeling was $75,000, Surface Modeling was $30,000, GRAFEM was $52,500, IFAD was $37,500 and Mechanisms was $30,000. In addition the Editor software cost $7,500 per workstation. The result was that a six color workstation VAX 11/780 system equipped with the full spectrum of design and analysis software could easily cost close to $1 million.

The reality was that most early Bravo! customers used the software for two-dimensional drafting rather than building solid models. According to the November 1984 issue of *Computer Aided Design Report*, Bravo! 1.0 had two major problems associated with it – it was slow and files sizes were excessively large. Fisher Controls, one of the early Bravo! installations stated that for some drafting tasks it was 20 to 30 times slower than earlier versions of Applicon's software. Another customer stated that drawing files were between six and 18 times the size identical drawings were on older systems. In late September 1984, Applicon began delivering Bravo! Version 1.5 which corrected many of the performance issues with two-dimensional drawings but did not address file size problems or solids modeling performance. *Computer Aided Design Report* recommended that customers considering installing Bravo! should definitely purchase the floating point option for the VAX 11/750, should buy an 800 MB disk drive as well the maximum amount of main memory and should install Applicon's new display list memory option in all terminals.[14] Two years later, performance issues, especially in regards to solids modeling, would still be haunting Bravo!.

Some users, however, were making progress with solids modeling, although not necessarily with Bravo!. The Endevco division of Becton Dickerson, a manufacturer of instruments for measuring vibration in aircraft engines and turbines started using Applicon's Solids Modeling software in early 1983. The company found that it could design transducer packaging in a third the time prior techniques took and that outside suppliers could produce more accurate prototypes faster.[15] It would be another decade before this attitude would become widespread within the mechanical design community.

As part of this round of product introductions Applicon also launched two low cost graphics terminals. The 4620 Desktop Color Raster Workstation included a keyboard and tablet combined into a single unit as shown in Figure 7.4 and a 13-inch monitor eight-color monitor with 672 by 504 resolution. The 4620 used an Intel 80186 microprocessor and included 256KB of program memory expandable to 756KB. An optional floppy disk drive was also available. This unit sold for just $17,500 which made it probably the lowest cost color raster terminal offered at the time by a major turnkey CAD/CAM system vendor. It was intended to be used by casual users rather than full time CAD operators. When this terminal was introduced in mid-1983, Applicon's announced plan was to upgrade it to support the CP/M-86 operating system in 1984 so that it could support application programs independent of the host processor.

A second workstation, the 4630 Modular Color Raster Workstation, was introduced at the same time. This unit also had a 13-inch monitor but with the same 768 by 576 resolution provided with the company's higher-end terminals. It was priced at $33,000 and was intended to be used by full-time operators as well as casual users. Applicon also introduced a new 4265 Graphics Processing Facility utilizing an upgraded VAX 11/730 computer with 2MB of main memory, a dual density (800/1600) magnetic tape drive and a 160MB disk drive. Without any terminals this unit was priced at $85,000, a substantial reduction from the price of the earlier VAX 11/730 systems offered by the company. The VAX 11/751-based 4275 Graphics Processing Facility was

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[14] *Computer Aided Design Report*, November 1984, pg. 8
[15] *Computer Aided Design Report*, January 1985, pg. 3

 

also repackaged with more memory and a lower price. VAX 11/780 customers needed to purchase two additional software modules in order to use BRAVO!, a Workstation Interface Module for $15,000 and a Peripheral Support Option for $5,000. The company claimed that an 11/780 system would support eight to ten workstations.

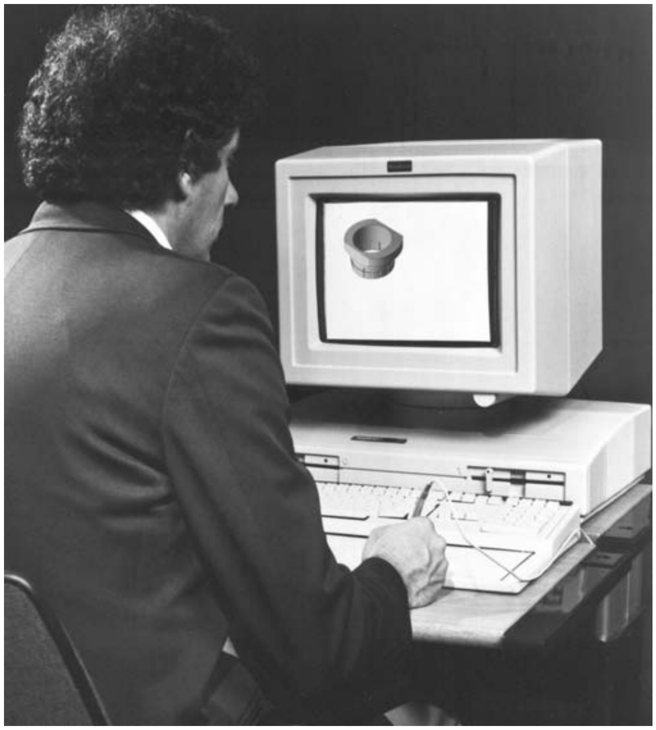

Figure 7.4
Applicon 4620 Low-Cost Terminal

There was one aspect of BRAVO! that would eventually prove to be Applicon's Achilles' heel. Early in its development, the decision was made by the company's software personnel to write BRAVO! in a new programming language called PL/1 that was being touted by many, including IBM, as being the programming language of the future. While a PL/1 compiler was readily available for VAX computers running the VMS operating system, similar compilers were not available for most other computer systems. As a consequence, this inhibited Applicon from porting BRAVO! to other platforms later in the 1980s and throughout the 1990s.

**Mid-1980s - tumultuous time for Applicon**

BRAVO! started off on a fairly positive note, at least publicity-wise. The company began shipments in July 1983 and later that year *Fortune* magazine named it a "Product of the Year."[16] The February 1984 issue of *CAD/CAM Alert* had an article discussing the successful implementation of BRAVO! by two long-time Applicon customers, Fisher Controls International in Marshalltown, Iowa and Gardner-Denver Compressors Division in Quincy, Illinois. Both were using the Solids Modeling II

[16] *Fortune*, "Products of the Year," December 12, 1983, Pg. 74

package, but not necessarily as their primary design tool. Moving data from legacy PDP-11/34 system required a translation process. Users with large databases of older design data such as Fisher Controls translated the data on an as-needed basis rather than trying to do it all at once. That company found that translation of geometric data went well while there were problems with the translation of textual attribute data. Apparently this article was written before Fischer Controls began experiencing the performance problems discussed in the *Computer Aided Design Report* article mentioned earlier.

Jim Sutton, the CAD/CAM project manager at Gardner-Denver wished that Applicon would “associate wireframe geometry with solids modeling in the database … to be able to make changes on the solid and have the wireframe be automatically updated.” Apparently the concept of an integrated database was not as far along as Applicon inferred during the product’s launch.[17] In early 1984, Applicon began shipping its new 4620 workstation with the CP/M-86 operating system. This enabled the unit to function as a PC when it was not doing CAD tasks. It does not appear that a user could be doing both types of tasks at the same time.

Don Feddersen was appointed general manager of Schlumberger’s Computer-Aided Systems Group in early 1984. In this role, he took a plan to Schlumberger management to more closely integrate MDSI and Applicon but was told that the corporate position was to break up organizations, not combine them. Shortly thereafter, Feddersen left to become a general partner at Charles River Ventures, a venture capital firm. Since 1997 he has been a private investor in high technology firms and has been a director of a number of such firms as well as a partner at Bessemer Venture Partners beginning in 2001. He has also been a long time director of Parametric Technology.

Feddersen’s resignation was the first of a number of management changes that would take place at the company as Schlumberger tried to determine the best model for its CAD/CAM businesses. Feddersen was initially replaced by Michael Pinot and eventually, as president of Applicon, by Alex Beavers, the former general manager of General Electric’s Intelligent Vision Systems Division. The hiring of Beavers was probably one of the reasons that led to Russ Henke leaving in October to become president of Gould’s Imaging and Graphics Division.

Beavers reported to Jimmy G. Lee, an executive vice president at Schlumberger who was responsible for the company’s Computer-Aided Systems Group. Other management changes included Edward Oakley joining the company from Hewlett-Packard as vice president of sales and a few months later and Jeffrey Simon joining as vice president of marketing. Dick Miller left the company in the summer of 1984. Miller, Jack Horgan and Jerry Sabath formed Aries Technology along with two others who had left Applicon earlier, Art McCray and Jerry Christopher. Aries was funded in part by Fontaine Richardson who was with Eastech and Art Reidel, a former vice president of engineering at Applicon who was with Alex-Brown and Company.

In the fall of 1984 Applicon began laying the groundwork for a workstation-based product. At the time, Apollo and Sun Microsystems were making inroads in the CAD/CAM industry through companies such as Auto-trol Technology, Calma, Mentor Graphics and Computervision. The first such product the company introduced was the Aria, a stand-alone color workstation that incorporated a Digital VAX 11/730 minicomputer. It appears to have been very similar to the previously introduced 4265

[17] *CAD/CAM Alert* – February 1984, pg. 4

 

Graphics Processing Facility with a 3MB main memory and a 13-inch 4620 Desktop Color Raster Workstation. See Figure 7.5.

Including database management, two-dimensional and three-dimensional design and drafting software, the Aria was introduced at $65,000 through the end of 1984. The initial price was expected to increase to $85,000 on January 1, 1985. After its initial introduction, several 19-inch color raster display terminals were added to the Aria product line. This was followed up at NCGA in April 1985 by the Aria II which replaced the VAX 11/730 with a MicroVAX II and support for a variety of Applicon terminals. The base price of the Aria II was $85,000 with shipments expected to start mid-summer. With a high resolution 19-inch display, an Aria II sold for as much as $125,000. At the same time, Applicon announced support for the new Digital 8600 "super VAX", VAX clusters and an interface to IBM mainframes.

Figure 7.5
Applicon Aria Workstation

The February 2, 1985 issue of the *Boston Globe* contained an extensive article on Schlumberger and its Applicon subsidiary that described in depth how the company's CAD/CAM market share had slipped precipitously since the Schlumberger acquisition. Lee was upbeat about the future claiming that it would take five years for Schlumberger to turn the business around and that they were only three years into the process. Lee had been with Schlumberger for 25 years and was a cigar chomping representative of the company's oil field roots.

Stanley Klein, who was then publisher of the *S. Klein Computer Graphics Newsletter*, was quoted as saying "What seems to be lacking at Applicon is entrepreneurial motivation. The question is whether a company with an abundance of resources can succeed in an extraordinarily fast-changing marketplace where the ground rules shift every six months."[18] Although the company was increasingly focused on the mechanical market, in March 1985 it established a new electronic design unit and hired Kenneth Jenkins to head it up.

The major issue for Schlumberger was how to structure Applicon and MDSI as complementary parts of the same business enterprise. In April 1985, MDSI announced that its Equinox NC software would be available on BRAVO! systems. MDSI also moved into the workstation market with a product called the Expert Station targeted at sheet metal design and fabrication. The company was also still balancing its mechanical and electronic software product lines. New Bravo! VLSI and PCB software that focused on graphical layout was introduced in mid-1985. This was at a time when the competition was making progress with systems that took a more logic-centric approach.

By July 1985 Applicon had shipped 100 BRAVO! systems but the company's market share was continuing to slip. While it had once been second only to Computervision, the company was now seventh in the industry with annual revenues of about $148 million.[19] Then Schlumberger decided it was time to reshuffle the deck once again. Applicon and MDSI were merged into a single company with Applicon becoming the name of the combined entity. By this point in time, the company was increasingly focused on the mechanical market and secondarily on electronic design. AEC applications were no longer a significant factor.

The company's headquarters were moved to Ann Arbor, Michigan, the home of MDSI, and Dick Mohrman who had been the general manager of MDSI became the vice president and general manager of the combined Applicon. Alex Beavers, the previous president of Applicon stayed with Schlumberger, but as vice president of marketing for the parent company's Computer-Aided Systems Group. During 1985 employment at Applicon dropped from 1,300 to about 600 in October.[20] Then in November, Rex Smith, who had joined Applicon in 1983, left to become president and CEO at CADSI, a vendor of mechanical analysis software.

**Applicon product line in early-1985**

This section describes the Applicon product line prior to the merger with MDSI. By early 1985, Applicon had stopped selling Digital PDP-11/34-based systems and was focused entirely on the VAX computer product line and BRAVO!. The VAX 11/730-based 4265 Graphics Processing Facility described earlier was now known as the 4130 BRAVO! Processing Facility. The company suggested that it could support four workstations which it probably could if they were simply doing drafting or wireframe design. If the systems was being used to support solids modeling, two workstations was a more realistic configuration.

In a similar manner the VAX 11/751-based 4265 Graphics processing facility was now known as the 4150 BRAVO! Processing Facility. The unit was being sold both as a BRAVO! platform and to provide VAX support for installed PDP-11/34 systems. The company claimed it would support eight workstations but four to six was probably a more practical limit. When Applicon introduced VAX-based systems, it only offered 11/730 and 11/751 computers as turnkey system components. Customers who wanted the larger

[18] *Boston Globe*, February 5, 1985
[19] *Anderson Report*, September 1986, pg. 4
[20] *Anderson Report* – October 1985, pg. 3

 

11/780 needed to purchase that computer directly from Digital. By early 1985, the company's sales strategy had changed and it now offered both 11/780 and 11/785 computers as the 4180 and 4185 BRAVO! Processing Facility.

The prices of color raster workstations (these were really terminals, not free standing or networked workstations) were starting to come down precipitously. In early 1985, the company was offering a variety of desktop and console units with either 13-inch or 19-inch color raster monitors. While monochromatic units may have been available, Applicon clearly was pushing color displays. The lower cost units had a resolution of 672 by 504 while the more expensive units were 768 by 576. As described earlier, the company offered an optional display processor called PERL that smoothed out jagged lines. It was good technology, but it did slow down the time required to generate a display. Most of the company's competitors were moving to higher resolution displays, specifically 1024 by 780 resolution units, to minimize the jagged line problems. In addition, the Applicon workstations did not support dynamic dragging of elements and the range of colors these units displayed was quite limited. The basic units were capable of just seven colors, preset by the factory. A 256 color option was available and necessary if the user wanted to visualize solid models.

One other problem with these terminals was that the link to the VAX was just 1.56 megabits per second. Generating new images was somewhat time consuming. Also, little was being heard from Applicon concerning the CP/M-86 operating system that was supposed to be available with the 4620 Desk Top Workstation. It did, however, emulate the Tektronix 4113 terminal, enabling the unit to support MDSI's NC graphics software on the VAX. The company was continuing to support the stand-alone ARIA but it did not seem to be a major element in Applicon's product line.

In early 1985, BRAVO! was still a work in progress. Early releases of the software had performance problems and data files were excessively large when compared to what was required with competitive systems. While performance improved with subsequent releases, the file size issue was intrinsic in the software. Both the performance and size issues can probably be traced to the fact that Applicon was using its Database Management package to store both graphics and attribute information. This software was based upon the SEED package described earlier but rewritten by Applicon in PL/1. It took some time to work out the bugs.

The Editor was the key user module. It was derived from the company's earlier Image package and retained that software's tablet recognition capability except that it now also supported on-screen menus. The on-screen menus were supplemented by a function keyboard with 64 buttons. Editor could display eight views of a design model and had geometric associativity as well as dimensional associativity. When an individual part was updated, all the assemblies that used that part were updated. Solids Modeler II used the same user interface as Editor. It was a CSG (Constructive Solids Geometry) modeler with eleven solid primitives.

Interactive images were generated using a faceted representation with the degree of faceting controlled by the user. The finer faceting used, the slower the responsiveness of the software. To perform hidden line removal, produce detailed shaded images or generate a boundary representation for drafting still required a conversion to Synthavision. The Synthavision boundary representation of the model could not be converted back to a CSG model.

 

Finite element and mechanism analysis has been described earlier. One application area where Applicon was having problems was with numerical control software. The solution was to implement MDSI' Compact-II NC part programming package on the VAX and interface it to BRAVO!. A package that would work directly with the BRAVO! database was slow in coming. This software did not have many of the capabilities competitors offered such as color-coded feed rates, dynamic tool motion or anti-gouging algorithms. Other applications available at this time included flat pattern generation, nesting and flame cutting, and technical documentation. The company had ported its PCB and integrated circuit design software to the VAX but it is not clear to what extent this was still original16-bit PDP-11/34 code versus rewritten 32-bit VAX code. The same comments apply to the company's architectural drafting and piping design software.

While prices were coming down, these were still expensive systems. A 4150 VAX 11/751 cost around $150,000. The workstations ranged in price from $17,500 to $42,500. In addition the Editor software cost $9,500 per workstation. In a departure from its previous software pricing strategy, Applicon no longer varied the cost based upon the size of the computer being used. Instead, it charged a flat amount per CPU and an additional amount per workstation. As an example, Solids Modeling II had a base cost of $20,000 plus $5,000 per workstation using the software. While this was probably competitive with other system running on VAX 11/780 or 11/785 computers, it was fairly expensive for smaller 11/730 and 11/750 configurations.

**Applicon becomes Schlumberger CAD/CAM Division**

At the May1986 NCGA Conference in Anaheim, California, Applicon announced a new release of its software product line, Bravo3 (apparently this was the new nomenclature for Version 3.0 of Bravo). At the same time it launched a series of new software packages for printed circuit board and integrated circuit design. When Schlumberger combined Applicon and MDSI into a single organization in July 1985, it had split the electronic portion of Applicon's product line off and assigned that business activity to another corporate organization, Factron, a manufacturer of electronic test equipment. That combination probably made sense to executives who were several levels removed from the technology and business issues of this industry but it was not an effective relationship. By early 1986 it was back as part of Applicon but the portion of the company's revenue represented by electronic design applications had slipped to around 10 percent.

The new Bravo3 electronic design software included schematic capture, design analysis, and the physical design of PCBs and integrated circuits. The PCB routing software was developed by Algorex, a PCB design and manufacturing company. This new software was introduced as being available on Sun Microsystems' workstations as well as on the VAX systems Applicon had traditionally supported.[21] A typical four seat VAX system sold for $600,000 including the routing software. [22] The company's objective, and one that it continued to pursue for a number of years, was to offer an integrated suite of electrical and mechanical design software. As an example, the combination of electrical and mechanical software could be used to design individual

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[21] *CAD/CIM Alert*, May 1986, pg. 2
[22] *Computer Aided Design Report*, August 1986, pg. 14

 

circuit boards, the product that these circuit boards were to be used in and then do a thermal analysis of the mechanical and electrical components. While this combination was attractive to companies designing electro-mechanical products, companies designing complex electronic systems, especially large-scale integrated circuits, were moving to more specialized software products offered by companies such as Mentor Graphics, Cadence and Daisy. One exception was Fairchild Semiconductor which was also a Schlumberger company.

Bravo3 was the nomenclature Applicon applied to the integrated database that supported the company's suite of design, analysis and manufacturing applications. By this point, Applicon had integrated the MDSI Equinox manufacturing software to work with Bravo3. All of these packages were available on the VAX VMS platform but only some, mostly electronic design-related, were also available running under UNIX on the Sun platform. The hardware portion of the product line consisted of two groups of products, the 4600 series which used Digital computers and the 4700 series which were Sun workstations with Applicon enhanced graphics. A color Sun-based unit, the 4735, sold for $59,900. One terminal being offered for VAX systems was the 4670 which had 1536 by 1157 resolution and supported 1,793 colors. This unit incorporated an Applicon built graphics processor capable of displaying 100,000 random three-dimensional vectors per second. An optional shaded image generator rendered up to 25,000 polygons per second. The basic unit sold for $59,000 while the shaded image option was an additional $9,000.

A few months later, at AUTOFACT '86, Applicon introduced Bravo3 3-D Mechanisms dynamic analysis software. This package tightly integrated Mechanical Dynamic's ADAMS (Automatic Dynamic Analysis of Mechanical Systems) and Bravo3 with a consistent user interface. A 2-D Mechanisms package incorporating MDI's DRAM (Dynamic Response of Articulated Machinery) software was also available from Applicon. Revenue at Applicon was up 18 per cent in 1986 from the prior year and Mohrman claimed the company made a profit for the year, its first in five years.[23]

While it was striving to regain its former sales momentum, management of Applicon was still in turmoil. Apparently 1986's financial results did not satisfy Schlumberger's management. In February 1987 Mohrman was replaced as vice president and general manager of Applicon by another Schlumberger executive, Bruce McCann, who had been with the company's North American Wireline operation. Like General Electric and its management of Calma, Schlumberger seemed to believe that general management experience was more important than specific knowledge of the CAD/CAM industry and its technology.

In what would eventually be seen as a significant move, Applicon decided to unbundle its software and price it separately from the hardware it also sold. This enabled customers to purchase standard computer systems and workstations from Digital and Sun and then purchase the software from Applicon. The problem with this approach was that Digital 's workstations were loosing the price/performance race compared to other workstation vendors and only a limited amount of Applicon's software ran on anything other than VMS systems.

At this point in time, the company was having a hard time getting the Bravo3 VLSI software off the ground and sales of that product was suspended in April 1987.

[23] *Computer Aided Design Report*, December 1986, pg. 10

 

According to Jerry Robertson, vice president of sales and marketing, "We are going to bite the bullet and hold off marketing Bravo3 VLSI until we are able to provide an efficient migration path for our existing users of IMAGE 860 systems."[24]

In March 1987 Applicon announced that it would market Sun-based UNIX systems starting at $12,900 for a system with a 19-inch monochromatic display and either drafting or three-dimensional design software. This was apparently a diskless node that required either a server or larger workstation in the network in order to function. The Sun version of the software was not pushed very aggressively and before 1987 was over Applicon was once again supporting just Digital hardware. At the same time it announced the Sun-based product, Applicon introduced the GW4790 workstation that incorporated a Digital MicroVAX II computer. It was priced from $45,000 with just basic operating system software to $95,000 with solids-based design and drafting software.

Schlumberger continued to periodically reorganize its computer-related business units. Around August 1987, the group referred to as Computer Aided Systems was eliminated and a new organization called Schlumberger Technologies was established consisting of Applicon, ATE (semiconductor test equipment) and Benson (plotters). Then in November, the Applicon name was dropped and it became simply Schlumberger CAD/CAM.

For the next year or so, there were few significant product or business announcements from the company. Finally, in September 1988 Schlumberger announced a number of new manufacturing-related software packages including BravoNC which was billed as "the first major technological advance in NC programming since APT."[25] What was significant was that this software could take a part that was made up of a number of independent surfaces and generate tool paths that smoothly machined across the intersections of these surfaces. The package sold for $19,800. Proceeding along this manufacturing path the company also introduced a new coordinate measuring machine programming package as well as a new sheet metal design and fabrication package. Schlumberger tried to get the message out that manufacturing was a core focus of the company by establishing a special interest group for users of its COMPACT II and BravoNC software. The group's first meeting was held in October in Dallas.

**Schlumberger launches MacBRAVO!**

In the late 1988 time frame it was not a foregone conclusion that the IBM-compatible personal computer running a Microsoft operating system would dominate the PC market. Apple had some very good products at the time and controlled a substantial share of the market, mostly due to its introduction in 1984 of the Apple Macintosh. The Macintosh is widely credited with being the first successful computer product that incorporated a graphical user interface, albeit one that the company appropriated from Xerox's Palo Alto Research Park.

While PC manufacturers were committed to using Intel microprocessors, Apple decided to use the far more powerful Motorola 68000 series chips in its products. In March 1987 Apple introduced the Macintosh II with a 16-MHz 68020 processor – the same processor being used by Apollo, Sun Microsystems and other manufacturers for high-end engineering workstations. With 1MB of main memory and a 40MB hard disk,

[24] *Anderson Report*, April 1987, pg. 8
[25] *CAD/CIM Alert*, September, 1988, pg. 8

 

the early Macintosh II sold for $5,500. The monitor was extra. Performance-wise it didn't quite compete with the more expensive workstations, but it was clearly superior to most PCs.

Schlumberger used the availability of the Macintosh II as an opportunity to launch a new software product line called MacBRAVO! Launched with much fanfare at AUTOFACT on October 31, 1988, the initial release consisted of two modules, MacBRAVO! MODELER and MacBRAVO! DETAILER. At the time, both Schlumberger and Apple felt that this was a significant announcement, sufficiently significant that both Euan Baid, Schlumberger's CEO and John Scully, Apple's CEO both showed up for the press conference where MacBRAVO! was introduced.

The two MacBRAVO! Software modules along with an IGES translator had a combined price of $3,295. It required a Macintosh II with 4 MB of memory so that the combined hardware and software price probably totaled around $11,000, substantially less than what the BRAVO3 system cost including a Digital VAXstation. Schlumberger presented MacBRAVO! as coming from the same code base as its BRAVO3 product line, but the overall functionality was a subset of BRAVO3. Data could be directly exchanged with VAX-based BRAVO3 systems but not with BRAVO3 running on Sun workstations. Also, there was no mention of any of the MDSI manufacturing software being converted to run on the Macintosh II nor of an interface to that software running on other platforms.

MacBRAVO! incorporated the pull-down menus and icons that were integral to the MAC Operating System. Consistent with BRAVO3, the Macintosh software also supported the company's unique Tablet Symbol Recognition capability although with a Macintosh mouse it was far more clumsy to use than on a workstation equipped with a tablet and stylus. The software supported up to eight windows, one of which could be active at a time. MODELER supported warped, swept and ruled surfaces, offset surfaces and surface intersections. In addition to direct translation between MacBRAVO! and BRAVO3 and an IGES 4.0 translator, Schlumberger also offered a AutoCAD DXF translator.

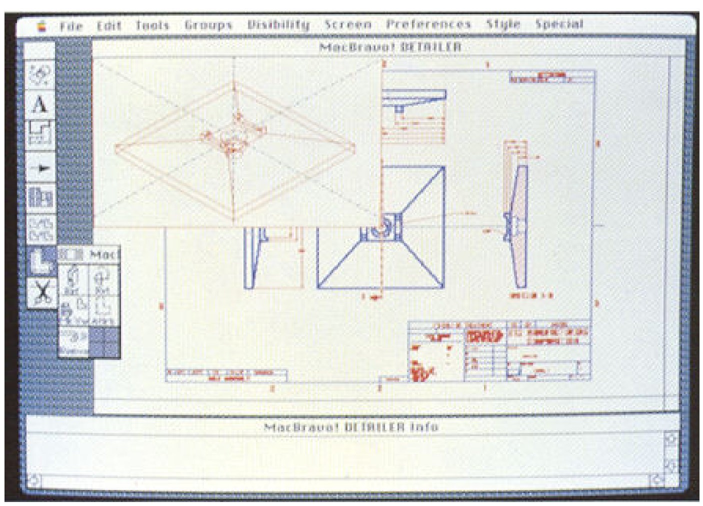


Figure 7.6
MacBRAVO DETAILER Showing Multiple Windows and Icon Menus

The primary competition for MacBRAVO! was AutoCAD. From a three-dimensional design perspective, AutoCAD did not compare to the modeling and surface geometry capabilities Schlumberger was providing. From a pure two-dimensional drafting point of view the two packages were comparable in creating geometric data but, based upon tests performed by Schlumberger, MacBRAVO! was nearly three times faster creating dimensions and other annotation. In addition, users could extract detailed part lists from MacBRAVO!'s three-dimensional models and the Macintosh version of the software could be used as a low-cost system to detail BRAVO3 designs.

Apple continued to market the Macintosh II through late 1993. The final model was the Macintosh IIvx which used a 32-MHz Motorola 68030 processor. Schlumberger, however, ceased promoting MacBRAVO! sometime earlier.

**Schlumberger CAD/CAM tries to find its niche**

For the most part, large corporations have almost always found it difficult to develop a meaningful CAD/CAM vendor business model. Schlumberger was no exception. The problem is that this was a very rapidly changing industry, especially in the late 1980s and early 1990s, that required managers to have a strong feel for what customers wanted if they were to be successful. Decisions had to be made quickly and there was little margin for error. Large bureaucratic organizations were not amenable to this type of rapid change.

Whether or not they were profitable activities, Schlumberger Technologies apparently realized in early 1989 that it had too many irons in the fire. Having earlier merged Applicon and MDSI into a single organization, the company decided that being in the plotter hardware business did not fit its long term objectives and it decided in March to sell its Graphics Division subsidiary. Originally known as Benson, this operation manufactured and sold electrostatic and pen plotters. In June it was sold to Océ, based in Venlo, The Netherlands. Basically, Schlumberger was getting out of the hardware manufacturing business. In early 1988 it had sold its graphics manufacturing operation in Billerica to a management group headed by Francis Donlan who had been the company's CAD/CAM manufacturing manager. Renamed Manufacturing Solutions, Inc., it continued to produce high-end graphics workstations that were sold by Schlumberger CAD/CAM.

In 1987, Applicon had introduced facility layout package, Bravo3 Facilities, targeted at large manufacturing plants. This was the first AEC package developed for the Bravo3 product line. It incorporated a variety of features that facilitated the design process including double line walls with automatic cleanup when doors or windows were added, three-dimensional machinery models, and the calculation of the length of electrical wiring. If the model of a piece of manufacturing equipment was changed, all instances of where the unit was used also updated. According to *The Anderson Report*, Applicon had committed to the development of this software for General Motors several years earlier in exchange for a 100 seat order. In June 1989, Schlumberger announced that it would deliver a Macintosh version of the software by the end of the year. MacBRAVO FACILITIES apparently had similar capabilities to the earlier VAX version of the software but the basic version sold for just $4,900. Including Macintosh hardware, a typical seat cost from $16,000 to $28,000, substantially less than minicomputer or engineering workstation systems from Intergraph or Auto-trol Technology but far more than AutoCAD running on a PC.[26] One of the company's more interesting marketing moves occurred in the spring of 1989 when Schlumberger CAD/CAM announced that for a limited time it would give buyers of Bravo a "free" DECstation 3100.

A more significant product introductions in this time frame was a software package called BravoMOST (Mechanism Optimal Synthesis Tool). This program could be used to assist in the design of two- and three-dimension mechanical linkages. The designer would create the basic design of such a linkage, indicate the points in space that a particular element of the linkage was to pass through, define which elements of the linkage assemble could be modified by the software and then have the program determine the optimum linkage design. BravoMOST eliminated the need for time-consuming iterative design procedures and physical prototypes. Schlumberger also introduced BravoDRAW, a low-cost mechanical drafting package, and BravoMODEL, a three-dimensional wireframe subset of Bravo3.

In mid-1990 Schlumberger CAD/CAM's relationship with Digital continued to be particularly strong. Other than the Apple Macintosh, Digital was the only platform being supported. Schlumberger was the largest single value-added reseller of Digital hardware. The previous December, the two companies had even agreed to have Digital distribute Bravo3 to its customers. One reason for the strong CAD/CAM relationship was the fact that Schlumberger was a major user of Digital computers for its oil and gas services business. The *Anderson Report* felt that this relationship had both positive and negative results. On the one hand, since Bravo3 was not available on competitive computer systems, the Digital sales people did not have to be concerned that potential customers might select a non-Digital platform on which to run the software. On the other hand, Digital was not winning many new customers and that limited Schlumberger to selling into Digital's installed base.[27] At this point, Schlumberger took another step in getting out of the hardware business by selling Digital its hardware test and repair business and turning over the maintenance of existing installed hardware to Digital.[28]

Schlumberger's European base was beginning to have a positive impact on its CAD/CAM business unit. In 1990, European business increased 25 percent from the prior year and the subsidiary opened six additional sales offices in East Germany, Turkey, Spain, Holland, France and Benelux. Schlumberger CAD/CAM Europe under Hans-Kurt Luebberstedt, vice president of sales and service, had expanded to 300 people handling sales and support.[29]

Overall, the company's revenue had changed little during the prior six years. From $141 million in 1985 it had peaked at $155 million the following year before dropping to $135 million in 1987. The following three years saw revenue in the $140 to $143 million range. What did change was the hardware/software mix. In 1985 it was 24 percent software and 76 percent hardware. By 1990 this had changed to 55 percent software and just 45 percent hardware. In 1990 mechanical software was 60 percent CAD and 26 percent CAM. Typical software prices per seat in mid-1991 were $15,000 for the basic Editor/Database Manager, $11,000 for Solids Modeler, $9,700 for Surface Modeler, $3,500 for BravoDraft and $15,000 for BravoNC.

[26] *Anderson Report*, June 1989, pg. 1
[27] *Anderson Report*, June 1990, pg. 4
[28] Schlumberger CAD/CAM press release, October 15, 1990
[29] Schlumberger CAD/CAM press release, undated

 

The company offered three different sets of products. Bravo3 Version 3 was the full function suite of design, analysis and manufacturing software available on the VAXstation 200 and 3200 and the MicroVAX 3500 and 3600. These machines were available running both Digital's legacy VMS operating system and that company's implementation of UNIX called ULTRIX. Schlumberger supported just VMS, however. The core package was Bravo3 Editor which supported both wireframe and solids modeling with shape libraries and feature-based modeling. A surface geometry module that supported NURBS surfaces was also available as were numerous analysis and manufacturing options.

DesktopBravo! was Schlumberger's initial package that supported ULTRIX. The DECstation systems were Digital's attempt to provide customers with a UNIX alternative to its VAX products. These machines utilized MIPS processors and ran UNIX but not VMS. Only two ULTRIX packages were initially available from Schlumberger, Detailer and Modeler. While the company promised more software options in the future, they were slow in coming. One problem probably was the lack of a PL/1 compiler for the DECstation which meant that Bravo3 software had to be rewritten, not just recompiled.

The third product line was the Macintosh software described earlier. It was not selling as well as Schlumberger had expected. During the first year it was on the market, only 1,300 seats had been sold. Meanwhile, Autodesk had sold over 300,000 copies of AutoCAD. In addition, the company signed an agreement with Parametric Technology to resell Pro/ENGINEER further confusing the product line in the minds of prospects.

**The Morley era begins**

In June 1991 Schlumberger switched management directions once again and for the first time brought in an experienced CAD industry veteran to head the CAD/CAM division. Bradford C. Morley had been a senior vice president at SDRC and in charge of its software business when he was recruited by Schlumberger Technologies to re-energize the company's efforts in the CAD/CAM area. He reported to Clermont Matton, the head of Schlumberger Technologies. Prior to taking over Schlumberger's CAD/CAM business, Morley had spent seven months at the company's headquarters in New York as vice president of marketing and business development for Schlumberger Technologies. Upon taking over the helm at Schlumberger CAD/CAM, Morley implemented a five-year plan to re-establish the company's momentum and to make it a major factor in the industry.

The plan, known as "Cresendo" internally, had seven key elements: multiple computer platforms, modular software, a common geometry engine, ease of use, simulation (analysis) technology, manufacturing software and data management. Gone from the company's business model was reselling hardware, electronic and AEC applications, and the reselling of other companies' software such as PTC's Pro/ENGINEER. The company also was not interested in selling stripped-down entry-level systems. Two other aspects of Morley's plan to turn the company around were to re-establish a brand identity and to eventually take the company public once again. After looking at alternatives such as sticking with the Schlumberger name or resurrecting the MDSI label, they concluded that the Applicon name still resonated with the company's users. So, on September 16, 1992, Schlumberger CAD/CAM once again became Applicon.

 

On the financial side, the plan was to go public in 1995 with Schlumberger continuing to hold 49 percent of the company's stock with the balance being sold to employees and the public. The company had revenues in 1992 of $104 million and at this point was a 600-person firm. Overall, the plan made a lot of sense but like all other such plans, the proof would be in the execution.[30] In addition to Morley, key managers included Warren Liu (marketing), Dan Presidio (engineering), Mike Anderson (North American operations), Hans-Kurt Luebberstedt (European operations), and Robin Kerr (Asia/Pacific operations). Within the marketing operation, Jim Fall was responsible for modeling software while Rod Nehring handled data management products and Brian Barton CAD/CAM applications. Software revenues had increased 21 percent in 1991 and the company planned to increase its research and engineering budget by 40 percent in 1992.[31]

The fact that Schlumberger CAD/CAM had over 4,500 customers including 300 new ones in 1991 but only 90 users showed up for the company's user group meeting in San Diego in April 1992 should have been an indication that something was fundamentally wrong with the company's marketing and support strategy.[32] The company had three major tasks on its hand at this point in time: 1) keep Bravo technologically competitive with up-and-comers such as PTC's Pro/ENGINEER, 2) maintain the revenue momentum of legacy MDSI NC software, and 3) figure out a way to port the PL/1-based Bravo code to new computer platforms.

In late 1992 Applicon launched Bravo Version 4 (the Bravo3 designation was dropped with this release) that implemented a new Motif-based user interface for several key Bravo modules including BravoDesigner (Editor), BravoSolids and BravoSurfaces, a geometric modeling technique called Dynamic Modeling, an interactive sketcher and substantial enhancements to most Bravo analysis, manufacturing and database modules. The new user interface featured icons, dialogue boxes, pull-down menus, pop-up tool palettes, and cascading menus. Version 4 was being offered on Digital's DECstations running ULTRIX and VAXstations running OpenVMS. Digital had earlier launched its new 64-bit Alpha processor and Applicon planned to support the AXP 3000 workstations that used this processor by late 1993.

The company was once again planning to support non- Digital platforms, this time Hewlett-Packard systems. The plan was to work with HP to develop a translator to convert PL/1 source code to C. The two parties believed that this would require less effort than writing a PL/1 compiler for the HP workstations along with all the support code that would be necessary. The project eventually turned out to be both a financial and technical disaster.[33]

The company's long term platform strategy was to function in a transparent heterogeneous computing environment. This would eventually mean that a customer could have a mixture of workstation from different manufacturers and Bravo data could be exchanged between workstations without user intervention. A major concern was that before this heterogeneous environment was available existing customers would switch to competitive CAD systems which ran on higher performance workstations than the Digital

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[30] *Engineering Automation Report*, August 1993, pg. 6
[31] Schlumberger CAD/CAM press release, February 4, 1992
[32] *Bravo News*, June 1992, pg. 5
[33] *Engineering Automation Report*, January 1996, pg. 6

 

systems the company then supported. In April 1993 Applicon announced four marketing plans to prevent this from happening. LeaseNow enabled customers, for a monthly lease charge, have Applicon take over the responsibility of periodically replacing their workstations with newer, higher performance units. AlphaNow enabled customers to purchase current Digital systems and eventually upgrade to Alpha systems at no additional cost. OpenNow enabled customers to use Hewlett-Packard workstations as client terminals with Bravo still running on a Digital system. MigrateNow was a trade-in program that offer discounts higher than Digital's standard trade-in discounts. The major problem with this strategy was that the port of Bravo to Hewlett-Packard UNIX workstations was turning out to be taking much longer than planned.

Perhaps the most significant feature of Bravo Version 4 was its new Dynamic Modeling capability. This technology, called *Degrees of Freedom Analysis*, had been jointly developed by Applicon personnel in Billerica, Massachusetts and the Schlumberger Laboratory for Computer Sciences in Austin, Texas. Most modeling systems at the time used either a propagational methodology where the sequence in which the model was created was critical to making changes, a variational methodology where each geometric constraint involved solving a set of equations or a combination of the two. Applicon's Dynamic Modeling did not require that a design be created in a specific sequence nor that the model be fully constrained at all times. The result was software that offered a good combination of flexibility and speed. In mid-1993 Dynamic Modeling supported two-dimensional sketching with three-dimensional sketching planned for Bravo Version 5 scheduled for 1994. This new version of Bravo was also expected to incorporate Spatial Technology's ACIS solids modeling kernel in place of Applicon's internally developed solids modeling software.

One of the nicer features of the new Bravo user interface was a dynamic slider bar mechanism. The user could select a particular element or dimension of a model to be modified. This element was then represented in a slider bar dialog box with limits initially set to half the current dimension of the item and twice the dimension. As the user mover the slider bar, the model would adapt to the change in the size of the selected element and consistent with previously defined constraints. It was a very slick technique that showed up well in demonstrations and was actually a fairly practical design tool as long as the model was not overly large and complex. See Figure 7.7.

In June 1993, Applicon hired Frank Stefanik as vice president of marketing and business development. Stefanik had been around the CAD/CAM industry for nearly 20 years including a stint at McDonnell Douglas where he was a senior vice president. Except for Morley, he was one of only a few experienced industry executives hired by the company during this period. During an interview in July 1993 for an *Engineering Automation Report* article, Morley was optimistic about the company's future. "If we have managed to do as well as we have with limited platform support, imagine what we can do when we are platform independent."[34] The company aggressively promoted its numerical control experience, stating that its software supported 30,000 machine tools around the world.

[34] *Engineering Automation Report*, August 1993, pg. 10

 

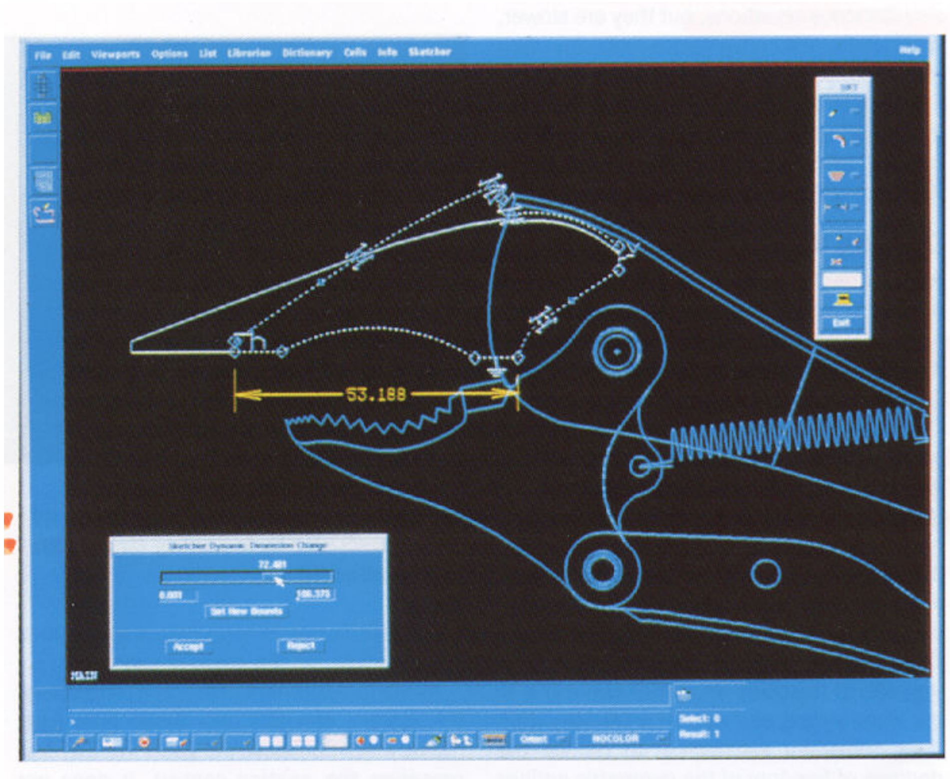


Figure 7.7
Bravo 4.0 Sketcher

**Gores Enterprises acquires Applicon**

Within a few months of my visit to Ann Arbor and the upbeat interview with Morley in July 1993, Schlumberger was approached by Alex Gores, the CEO of what was then known as Gores Enterprises and today is called Gores Technology Group, with an offer to acquire the company's Applicon subsidiary. Based in Los Angeles, Gores mode of operation was to acquire technology-related companies that were subsidiaries of larger companies, pare down the staff and overhead expenses and focus of selling products and services to the acquired organization's existing customer base. It had previously done just that in early 1992 with GRAFTEK, a division of Unisys, that developed and sold mechanical design and NC software for the tool and die industry. Gores had also recently acquired the service business of NBI, a vendor of specialized word processing systems. In future years, Gores would become a very large buyout firm handling deals as large as Learning Company, the money loosing software maker that Mattel had earlier bought for $3.5 billion.

(As an example of some of the convoluted inter-relationships in the CAD/CAM industry, Gores at one time owned a company called Ventech that developed software products for the building materials industry. Ventech was subsequently sold to MAI Systems which became a key component of MAI Basic Four, the company Bennett LeBow used in his unsuccessful attempt to take over Prime Computer and its Computervision subsidiary.)

 

The acquisition of Applicon by Gores was announced on September 28, 1993. Schlumberger most likely decided to unload Applicon after twelve years because it didn't see any light at the end of the tunnel. The CAD/CAM industry was going through a massive transition, moving away from turnkey systems to selling unbundled software. This changed the economic foundation for companies such as Applicon which had seen its annual revenue drop from over $100 million to just $70 million. Most likely, this had resulted in Schlumberger incurring losses which the company no longer was interested in absorbing.

The major concern voiced by industry observers such as *Engineering Automation Report* was that the new owners of the company would slow down development of new software and stop the fairly costly project to make the software multi-platform. The same day the proposed acquisition was announced, Applicon described Bravo Version 4 Plus which had been undergoing beta testing at customer sites including Figgie International. This version of Bravo was intended to support Digital's new Alpha workstations running OpenVMS. Figgie reported that the Alpha-based Digital 3000 Model 300 and Model 500 were two to four times faster than the DECstation 5000 when doing graphics tasks and ten times faster when doing computationally intensive work.[35]

When the acquisition was announced, the statement was made that the plan was to operate GRAFTEK and Applicon as separate entities. Within a few months Morley was replaced as president of Applicon by Vance Diggins, a long term Gores associate and most recently president of Gores' Graftek subsidiary. For the most part, Diggins ran Applicon remotely from an office in Boulder, Colorado and spent a significant portion of his time working on new deals for Gores rather than managing Applicon's day-to-day business. The latter task increasingly became Stefanik's responsibility.

The relationship between Gores and Schlumberger got off to a rocky start. Gores felt that Schlumberger had misled it concerning the financial condition of Applicon at the time of purchase and in the spring of 1994, it withheld some payments due Schlumberger. Schlumberger retaliated by sending letters to some Applicon customers requesting that they make maintenance payments directly to Schlumberger and not to Applicon. With users caught in the middle, the two companies renegotiated the terms of the acquisition and this storm soon became history.[36]

One immediate result of the Gores acquisition, however, was a slowing down of software development. Bravo Version 5 was originally scheduled to be released in 1994. In April 1995, the company announced Bravo Version 4.9 with just nominal enhancements. The press release for Version 4.9 promoted features such as the slider bar interface tool described above which had originally been released several years earlier with the initial Version 4 software. Another significant change was that Bravo now supported both its new MOTIF user interface as well as the original Bravo interface, making the transition to the new version easier for user organizations. The company also drastically changed how Applicon systems were sold. It did away with its vice president of sales and shut many of its European and Asian sales offices. These territories were taken over by distributors, some of whom were ex-Applicon employees.

Later in 1995, Michael Oehler, who had been president of Gores' GRAFTEK subsidiary, was moved over to Applicon as vice president of business development with

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[35] *Engineering Automation Report*, November 1993, pg. 12
[36] *Computer Aided Design Report*, January 1995, pg. 10

 

specific responsibility for sales and marketing activities in the Asia/Pacific area, especially China. It is not clear how much the company shrunk after Gores took over. One publication put the revenue at $35 to $37 million and 185 employees in early 1995[37] while another publication said that the company had nearly $50 million in annual sales and was doing it with 200 employees as of late 1995.[38] Applicon's target market space consisted of companies that designed and manufactured mechanical machinery – especially industrial equipment built to order or in small to medium volume. About 58 percent of its business was in Europe with Germany its largest single market in that area.

**Applicon as a Gores Company**

In late September, 1995 Applicon finally released Bravo Version 5.0 which incorporated the ACIS modeling kernel from Spatial Technology. This precise boundary-representation modeler was marketed as a separate module called BravoSolids XL. It supplemented the faceted modeling technology that had been used in all previous versions of Bravo. Legacy faceted models could be directly regenerated as precise models in 5.0 and precise models could be converted back to faceted models. The new software facilitated the creation of hybrid models consisting of wireframe, surface and solid elements. Bravo 5.0 also implemented new NC software for controlling newly introduced mill-turn machine tools. While Bravo 5.0 was a significant improvement over earlier version, it was, for the most part, playing catch-up with the company's primary competition. In a rather unexpected move, Applicon provided the media with a Bravo development roadmap up through Bravo 7.0 targeted for release in the fourth quarter of 1997, nearly two years in the future.

By early 1996, Gores had turned Applicon into a profitable business enterprise. The company had slimmed down from 600 employees at the time of the acquisition to about 200. Part of this reduction came from the termination of the PL/1 to C conversion project while other layoffs involved a dramatic decrease in the company's marketing organization. The company claimed that by the beginning of 1996 it had paid off the purchase cost to Schlumberger and that the company was debt free. Revenue was in the $50 million range and the company was profitable.[39] With a smaller staff, developers were able to obtain input directly from users rather than having it filtered by marketing since there was very little marketing left in Ann Arbor.

Under Gores management the on-going conflicts between the MDSI and Applicon forces within the company were finally contained. This was important because, increasingly, Applicon was pursuing small to medium size manufacturers who needed effective NC software. BravoNCG (G stood for graphics) used legacy MDSI Compact II technology that directly linked the part programming process to specific machine tool/controller combinations without the need to use a post processor. This was particularly important in regards to new machine tools and controllers that used complex canned cycles or sequences of operations. One problem at this point in time was that the NC software still used the older Bravo user interface.

The platform portability issue also was becoming more manageable. Instead of continuing the technically difficult PL/1 to C converter development, Applicon was now

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[37] *Computer Aided Design Report*, January 1995, pg. 10
[38] *CAD/CAM Watch*, Technicom, Inc., November 1995, pg. 1
[39] *Engineering Automation Report*, January 1996, pg. 7

taking advantage of new compiler development technology. Since many other companies with Digital and IBM PL/1 legacy code were moving to UNIX workstations and servers, a cottage industry had sprung up providing PL/1 compilers for these software firms. Applicon contracted with several of them to provide PL/1 software that would enable the company to port Bravo to Hewlett-Packard’s HP/UX operating system in early 1996 and Microsoft’s Windows NT later that year or early 1997. *Engineering Automation Report’s* biggest concern about Applicon at this point in time was that although the company had a well thought out product development strategy, the company needed to accelerate its schedule for these developments if it were to remain competitive in a rapidly changing industry.

Gores Enterprises subsequently used Applicon as a vehicle for acquiring several other small technology companies. It set up a subsidiary called Applicon Holdings for this purpose. Two such acquisitions were made in January 1996. The first was, HoSoft GmbH of Munich, Germany, a developer and supplier of engineering data management and product data management software. Applicon had been using HoSoft’s CORA II software as an integral part of its BravoFrame PDM package used by over 120 companies.

The second company was Computer Design, Inc. of Grand Rapids, Michigan, acquired from Masco Corporation. CDI’s key product was U4ia (pronounced Euphoria) which at the time was one of the best software packages available for visualizing fabric material. Use of this software varied from automotive seating design to fashion design. I was hired by Vance Diggins to help evaluate this business opportunity and was very enthusiastic about the potential of merging Applicon’s modeling technology with the visualization tools provided by CDI. For several months, I tried to convince Diggins of the market opportunity for technology that would enable high-end retailers to offer clothing tailored to the shape and size of individual customers. Unfortunately it was an idea before its time and Gores put little money into advancing CDI’s technology and the company soon faded into the background.

In March 1996, Applicon was finally able to announce support of Bravo on Hewlett-Packard Series 9000 UNIX workstations. By mid-1996, Frank Stefanik had the title of executive vice president and chief operating officer. In July, Bravo Version 5.5 was released with support for personal computers running Microsoft’s Windows NT operating system. BravoPiping, which was used extensively by German shipyards, now incorporated the ACIS kernel. Other enhancements included a streamlined user interface, the ability to open large assemblies significantly faster and support for the latest machine tools. In August the company introduced a new NC simulation package using software from Sirius Systems. On September 11, 1996 Stefanik became president and CEO of the company. Diggins was promoted to the position of president of the newly renamed Gores Technology Group.

Several other products were launched around this time including BravoSAT_MFG for importing parts and assemblies from other packages that used the ACIS kernel. The company also indicated renewed interest in DesktopBravo software with improved PC versions of Modeler and Detailer running under Windows NT. A few months later, Applicon announced that it would be utilizing a number of additional Spatial Technology products including Advanced Blending and Local Operations as well as ACIS Shelling from Geometric Software Services. The company’s soon implemented applications using ACIS 2.0 with these capabilities as well as user interface enhancements, three-dimensional piping design on the Windows NT platform, and more extensive use of ACIS modeling capabilities such as variable radius fillets and the shelling of thin-wall parts.

Bravo Version 6.0 was released in early 1997 and then Bravo 6.5 in December 1997 with a number of useful enhancements including dynamic dimensioning, isometric dimensioning, compound blending of solids models, three-dimensional piping isometrics, input and output of STEP AP203 assemblies and a new photorealistic rendering module using NuGraf from a company called Okino.

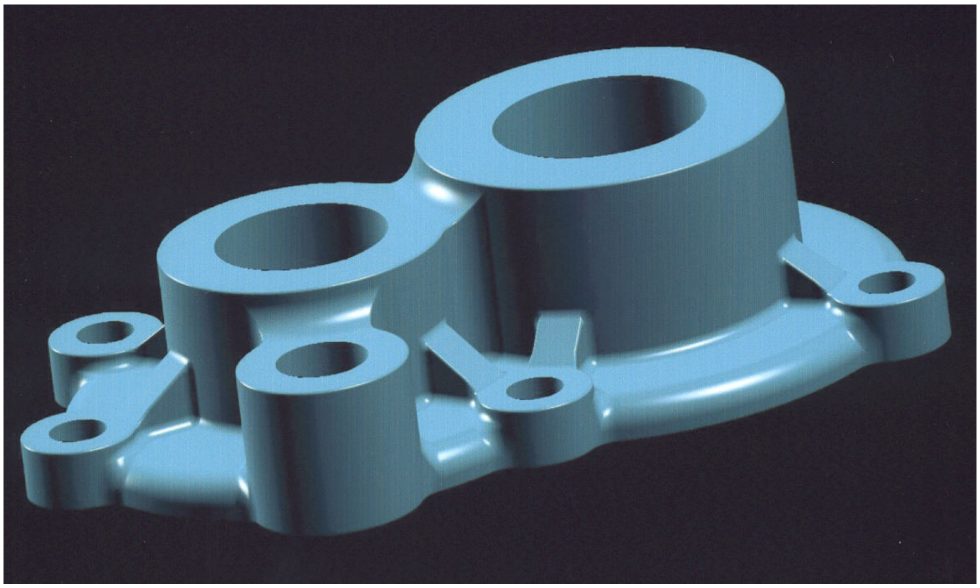

Figure 7.8
Solid Model Built with Bravo Version 6.5

**Applicon's slow fade into the sunset**

Over the next two years, Applicon continued to add functionality to Bravo in terms of improved modeling capabilities and new applications with the focus continuing to be a the manufacturing side of the business. Revenue continued to slowly decline as the company had less and less of its income coming from the sale and support of hardware products. By 1998 revenue was down to approximately $40 million annually. There were still approximately 5,000 customers utilizing 40,000 seats of Applicon software. Late in 1998, the company announced Bravo 7.0 that contained a number of enhancements that facilitated the modeling of large assemblies.

Bravo 7.0 also proved users with a "top-down" mode of product design. This methodology enabled users to design individual parts within the context of an assembly. As an example, if a user were to change the size of a particular part, it would be immediately apparent what other parts were affected by this change. The new release also contained a number of new techniques for defining the relations between individual parts in a large assembly. Bravo's built-in Librarian and its Product Data Management module, BravoFrame, were particularly well suited to managing all the parts that went into large assemblies. According to *Engineering Automation Report*, one Applicon customer had modeled a complete submarine in solids with 35,000 individual parts.[40] Version 7.0 also saw new sheet metal design and fabrication applications.

By 1998 the CAD industry was becoming divided into two primary camps: the large vendors who sold fairly expensive comprehensive suites of tightly integrated software packages and the mid-range vendors who sold lower cost packages with less functionality than their more expensive competitors. Applicon tried to be a little bit of each. Its software no longer matched the functional richness of its high-end competitors such as PTC, Dassault Systemes or Unigraphics Solutions so the company dropped its prices closer to what the mid-range vendors were charging. Applicon also promoted aggressively the fact that its software was available on PCs running Windows NT as well as on UNIX workstations. Customers were able to mix NT PCs and UNIX workstations in a single design environment and readily share data transparently between the two types of systems.

Announcements and product availability continued to lag. It was March 1999 before the new sheet metal design software began shipping and the manufacturing software was delayed until the second quarter of that year and then further delayed to summer. Once *Engineering Automation Report* got a chance to review Applicon's latest Version 7.5 sheet metal design software it was particularly impressed with its capabilities.[41] But other than the new sheet metal software there was little of significance happening at Applicon by this point.

**The end of the road**

The end of the road for Applicon came in August 1999 when Unigraphics Solutions (now a Siemens subsidiary) announced that it was acquiring Applicon. Gores' management had decided to sell Applicon and they approached UGS with an offer to acquire Applicon's engineering personnel as well as the company's customer base which nicely complemented UGS' own customers. At this point, the company had annual revenues of less than $30 million, much of which was most likely from software maintenance rather than new license sales. UGS reportedly paid less than $10 million for what was left of the one-time number two player in the industry.[42] From a product point of view, the biggest question was how would UGS handle the fact that Bravo was based upon Spatial Technology's ACIS geometric kernel when it developed and marketed Parasolid, ACIS' primary competitor?

The ACIS issue did not become important as UGS never seriously tried to take advantage of the Bravo software technology. The key rationale behind the acquisition was that it had acquired 60 programmers who were less than 50 miles from UGS' major automotive customer base in Detroit at a point in time when it was very difficult to hire competent programmers. Except for some sales people, most of the Applicon personnel stayed with UGS. One exception was Frank Stefanik who stayed with Gores. Initially, the former Applicon employees reported to Raj Khoshoo who was responsible for UGS' I-MAN product data management software. They were cross-trained in I-MAN and other UGS products as well as put to work on some integration projects.

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[40] *Engineering Automation Report*, October 1998, pg. 6
[41] *Engineering Automation Report*, June 1999, pg. 4
[42] *Computer Aided Design Report*, September 1999, pg. 16

 

Applicon customers who were on maintenance contracts were given the option to continue using Bravo or switching to UGS software products such as Unigraphics or Solid Edge. UGS came out with one additional release of Bravo, Version 8.0. Eventually most of Applicon's users switched to Unigraphics while some started using the company's Solid Edge software which UGS had earlier acquired from Intergraph.

# Chapter 8

# Autodesk and AutoCAD

Autodesk as a company, has gone through several distinct phases of life. There were the "Early Years" which covers the time from when Autodesk was founded as a loose programmer-centric collaborative in early 1982 to the company's initial public offering in 1985, the "Adolescent Years" during which the company grew rapidly but seemed to do so without any clear direction and the "Mature Years." The beginning of the latter phase began when Carol Bartz became president and CEO in 1992 and continues to the current time. Even under Bartz, there were several well defined periods of growth as well as some fairly stagnant years.[1]

**Mike Riddle gets hooked on computers**

Mike Riddle was born in California with computers in his veins. In junior high school, he built his first computer out of relays. It didn't work very well, but it convinced him that computers were going to be an important part of his life.

After attending Arizona State University, Riddle went to work for a steel fabricator where he had his first exposure to CAD. The company had a $250,000 Computervision system that, although capable of 3D work, was used strictly for 2D drafting. The company was engaged in doing steel detailing for the Palo Verde nuclear power plant in Arizona. Riddle felt that anything they were doing on this project with the Computervision system could be done on a microcomputer-based system. About the same time Riddle began working at a local Computerland store where they provided him with free computer time to do with as he wanted.

Meanwhile, out in California, John Walker, who had a BS in general engineering from Lehigh University, started a computer business in 1977, Marinchip Systems, which provided systems built around the TI 9900 microprocessor.. Dan Drake, who was to be a key player in this story, joined Walker at Marinchip in 1979. Previously he had been a consultant involved in computer-aided manufacturing. By this time, Riddle was a self-employed computer consultant. He produced some utility programs for Walker and Drake that they included with their early systems.

Starting in 1977, Riddle began working on a graphic program he called Interact. At the same time, he was working as a consultant for the Frank Lloyd Wright Foundation in Scottsdale, Arizona developing an accounting system for the foundation. In the process, he became the organization's computer guru. This provided him an opportunity to observe their design process, and Interact began to be used for some actual architectural work.

[1] The early portion of this chapter is based upon an extensive interview with Mike Riddle on April 28, 2001, an article written by David Cohn in the February 2001 issue of *Engineering Automation Report*, *The Autodesk File* by John Walker as well as updates on Walker's web site plus other historical material. The bulk of *The Autodesk File* consists of a series of "Information Letters" written by Walker or Dan Drake. These are often referred to by number.

 

**Organizing a new type of software company**

In late 1981, the 33-year old Walker and Drake who was 40, invited 14 friends to a meeting at Walker's home in Mill Valley, California where the seed was planted for organizing a new software company. The plan was to publish software programs developed by individuals who would be partners in the endeavor. Most of the people he invited to join the company were still employed by other firms and the concept was that they would develop new software in their spare time. Each principal was expected to kick in a minimum of $3,000 to start the company, although physical items such as computer hardware used for software development could be counted against this commitment.

A total of 18 people, including Riddle, Walker and Drake, were involved in starting a company in early 1982 that was initially called Marin Software Partners. One person dropped out fairly soon leaving 17 principals. Between them, they put up $59,000 to start the business, with much of the seed money coming from Walker's Marinchip Systems.[2] The small amount of startup capital was a far cry from the millions of dollars venture capitalists put into new companies today

Considerable discussion went into how the company should be organized. While Walker acknowledged that a corporation would be best, he was very concerned about the way software royalties would be treated for tax purposes in a corporation. In an early document, he went into some depth concerning the perceived advantages of a partnership versus a corporation.[3] Therefore, for the first few weeks the business functioned as a partnership. Fairly soon, however, everyone became convinced that this was far too awkward and on April 26, 1982 the company was formally incorporated in the state of California as Autodesk.

It is interesting to note in these early 1982 documents the extent to which Walker seemed to be obsessed with tax issues. Eventually, he would move to Switzerland, in part to avoid U.S. taxes.

Approximately 59,000 shares of stock were issued to the original 13 California-based partners at $1 per share. It turned out that there were some legal restrictions that prevented the European partners from being initial stockholders. By mid-2007, each of these original shares was worth the equivalent of about $7,500. Since none of the founders were drawing salaries (they all had other jobs), this small amount of startup cash was sufficient to start the company. Autodesk's cash balance never dropped below $25,953, a far cry from the nearly $1 billion it has on hand today.

**Interact emerges as lead product**

In *Information Letter #1*,[4] Walker listed 15 different programs that the founders were already working on or had the expertise to develop. The majority of these programs were what could best be described as system utilities, such as a filing program originally called Cardfile. Some exceptions included a program for lens design (LENS) and a PERT-like Executive Planning Aide. The most significant program out of the 15, however, was clearly Interact.

Riddle signed a non-exclusive licensing agreement with Autodesk for Interact in return for royalty payments. It is possible that Walker was willing to take on this software

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[2] Today, Autodesk has a market capitalization of nearly $10 billion.
[3] Walker, John, *The Autodesk Files*, Pg. 28
[4] Walker, John, *The Autodesk Files*, Pg. 28

 

on a non-exclusive basis because he underestimated its market potential. One concern he had was that it would require a hard disk or at least double-density double-sided 8-inch floppy disks, both of which were fairly expensive at the time. The terms of this agreement would eventually result in major disagreements between Riddle and Autodesk. More about that later.

Figure 8.1
Autodesk Founders
(From left to right: Rudolf Kunzli, Mike Ford, Dan Drake, Mauri Laitman, Greg Lutz, David Kalish, Lars Moureau, Richard Handyside, Kern Sibbald, Hal Royaltey, Duff Kurland, John Walker, Keith Marcelus)

**The names keep changing**

Shortly after starting the company, Marin Software changed the name of Interact to MicroCAD. At the same time, the filing program, Cardfile, was renamed Autodesk. On March 19, 1982 these two programs were shown at the 6th West Coast Computer Faire. The company paid $1,200 for a booth at the Faire, probably the best marketing investment ever made by a company in the software industry. It was around this time that

 

Walker came to the conclusion that a partnership arrangement involved more problems than it was worth and that the company would be incorporated instead,

Walker and his partners spent a fair amount of time struggling to come up with a company name that would be acceptable to the California regulatory authorities. At the Faire they used the name Desktop Solutions. That name was rejected by the state as were several other alternatives submitted by the company. By April 9, 1982 the company gave up on finding a cleaver name and simply used Autodesk in the papers it filed for incorporation, with the expectation that they would find a permanent name at a later date. That never happened.

**AutoCAD starts to gain traction**

Riddle continued to develop both CP/M and IBM PC versions of the software independent of the work being done at Autodesk on what was now being called AutoCAD. In fact, after the license agreement was consummated, Riddle had little involvement with the Autodesk version of the software. One of the major tasks at this point in time was converting the original Interact software to the “C” programming language for the IBM PC. First pre-release shipments were in late August 1982.

Meanwhile, the other founders continued to work on a program they called Window (a screen editor that was subsequently called Autoscreen), a spreadsheet program called OptiCalc, a BASIC compiler, and several other programs. It was not yet clear that AutoCAD would eventually dominate Autodesk and the lives of everyone associated with the company.

The turning point came when the company participated in COMDEX in November 1982. The CAD software shown at that conference was AutoCAD-80, so named because it ran on machines powered by either the Zilog Z80 or Intel 8080 microprocessor. Another company had appropriated the MicroCAD name sometime after the West Coast Computer Faire and before COMDEX, necessitating another name change.

This early version of AutoCAD proved to be one of the hits of the show. Several other vendors (Sierra Data Systems, Sun Flex, and Victor demonstrated AutoCAD in their booths and the software was awarded “best of show.” For a while, the Victor 9000 version was the most popular, because the Victor had the highest resolution screen of any PC, 800 by 400, and dual, high-density (1.2MB) floppy drives were standard. Readers need to remember that this was the point in time when the PC industry was just starting to take off. New manufacturers were coming out of the woodwork, not unlike the dot com boom 18 years later. This initial version of AutoCAD consisted of approximately 12,000 lines of source code. The first revenue copy of AutoCAD was sold to Jamal Munshi, the president of MOMS Computing in Sausalito, California..

Sales continued to be fairly slow until a new Intel 8086 version, written in C and called AutoCAD-86, was released in January 1983. Both versions were priced at $1,000. A dimensioning package was being developed that was to sell for an additional $500. It would eventually be combined with other features and sold as ADE-1 (short for AutoCAD Drafting Extension). Sales during that first year ending January 31, 1983 were $14,733 and the company lost $9,465. This was a far cry from the nearly $2 billion in annual revenue the company would generate several decades later.

The IBM PC version was what enabled the company to shift into high gear. The first mention of AutoCAD in an industry publication may well have been a brief article in the April 1983 issue of the *Anderson Report on Computer Graphics* which noted that the company had sold 400 copies of AutoCAD.[5] During calendar1983, Autodesk sold over 1,000 copies of AutoCAD and grossed more than $1 million. With a winner in hand, development on the other Autodesk packages was put on the back burner.

**Adding marketing to the mix**

As the company shifted into high gear, it hired its first marketing person, Mike Ford, who had been working in a computer store in Sausalito. He joined Autodesk on June 1, 1982 although it appears that initially this was on a part-time basis. According to Riddle, Autodesk would never have succeeded without Ford's involvement. Walker had a reputation for being able to write software code quickly, but was not known as a good program architect. He was also not particularly easy for most people to work with. Walker's management style was to try to run the company by telephone rather than having face-to-face meetings with employees. This was not particularly conducive to being a market-centric executive, hence the need for someone like Ford.

An article written by Rik Jadrnicek in the January 1984 issue of *Byte* magazine particularly excited the company.[6] Although the article did not emphasize AutoCAD, it did provide some credibility for micro-based CAD software. The most impressive illustration in the article was a view of the Golden Gate Bridge drawn in the summer of 1983 by a student, Malcolm McCullough, using an early version of AutoCAD. Perhaps it was no coincidence that Jadrnieck was a microcomputer consultant in Mill Valley, California.

**Autodesk becomes a real company**

The huge surge in business activity in 1983 did not come without some traumatic changes in running the company. Starting in late 1982 but picking up momentum in early 1983, Autodesk began to make the transition from being a rather loose collection of part-time software developers into a real company. Perhaps the most pressing problem was how the original partners could make the transition to being full-time employees.

Greg Lutz, who had been working full time on AutoCAD-86, was the first employee at a salary of $1,000 per month starting in January, 1983. The company was still not sure that the business would be successful, so the agreement with Lutz was initially for just four months. Dan Drake and Duff Kurland also expressed an interest in working full time for the company. In addition, Mike Ford replaced Jack Stuppin on the board of directors. Stuppin had been the company's early financial advisor but felt that he had a conflict of interest in continuing on the board.

Autodesk was also getting more serious about the sales side of the business. In December 1982, Mike Ford agreed to work full time for a 10% commission up to a maximum of $6,000 per month for the next three months with the commission rate dropping thereafter. For the most part, the company was looking at contacts Marinchip Systems and Walker already had to help the company move software. One of these, a

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[5] *The Anderson Report*, April 1983, Pg. 1

[6] Jadrnicek, Rik, *Computer-Aided Design- Significant CAD power is coming for desktop minicomputers, Byte Magazine,* January, 1984

 

company named Sun-Flex, was expected to sell up to 300 copies of AutoCAD per month combined with Sun-Flex's Touch Pen hardware. By June 1983, Autodesk had shipped 370 copies of AutoCAD to Sun-Flex, although it is not clear how many of these were actually sold to end users.

In general, early marketing focused on finding hardware vendors who would OEM AutoCAD (for around $450 per copy) and include it with the hardware they sold. As an example, the company was enthused about the prospect of Texas Instruments including AutoCAD with an IBM PC clone TI was planning to introduce. They thought this might result in the sale of 10,000 copies.

Several trade shows Autodesk attended early in the year (CADCON and CPM-83) made the firm aware that it needed some people who could effectively demonstrate AutoCAD. For the most part the company was staffed with programmers, none of whom except for Mike Riddle had any drafting experience, and Riddle was back in Arizona most of the time.

Three releases of AutoCAD were made during 1983 – 1.2 in April, 1.3 in August and 1.4 in October. By September the company was starting to talk about adding 3D capabilities to what up until then had been a 2D drafting package.

**Establishing a business presence**

By mid-1983 the company actually had an office. Until then, they had been operating out of their own homes or Marinchip Systems' facility. The first office was at 150 Shoreline, Building B, Room 20 in Mill Valley, California. At that point, the company hired its first customer support representative. The office was not big enough for all the company's activity, however. As an example, Mike Ford still handled sales out of his home. Ralph Grabowski recalled Lionel Johnston[7] telling him about a visit there. He said Mike's living room was filled with Victor 9000 computers, and Mike was sticking in and pulling out diskettes as they made copies of AutoCAD.[8]

At this point, the company had made the transition from a software publishing business utilizing the efforts of multiple independent programmers into a classic small company with a single product – AutoCAD. By mid-1983, the drawings this software was capable of producing were starting to approach the real world needs of drafters.

During 1983, Autodesk started recognizing the need for more formal software development practices – simple things, like an organized bug reporting process. There was still no clear distinction between marketing and sales. At a June meeting, John Walker filled in for Mike Ford in providing a marketing report. It was strategy and deal centric. On the other hand, Richard Handyside, reporting on activity in England, spoke about specific numbers of product demonstrations and dealer contacts. Walker estimated that as of late June 1983, or a little less than 18 months after it was started with a capital infusion of $59,000, the company had a value of about $200,000.

June 1983 was a key inflection point for the company. It moved from a group of programmers, each working on projects of their choice, to a company with the kernel of a business plan, an organizational structure, and even budgets. For the typical free spirited programmers of the early 1980s, these were traumatic changes. Walker proposed that the company be split into three divisions: marketing under Mike Ford, operations under John

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[7] Johnston was the founder of *CADalyst*, a magazine that initially focused strictly on AutoCAD.
[8] Personal discussion with Ralph Grabowski

 

Kern, and technical under Dan Drake. Proposed monthly budgets for these three groups were $14,000, $10,500 and $10,500 respectively. A subsequent report written by Kern Sibbald in early July indicates that Drake did not take over the technical division and that position was still considered open.[9]

Two non-stockholders were hired on a half-time basis—Jane Kern and Kathy Marcelus, the wives of John Kern and Keith Marcelus. As the year progressed, additional stockholders gave up their day jobs and joined Autodesk on a full time basis. By early July four were on board: John Kern, Keith Marcelus, Greg Lutz and Duff Kurland. Jack O'Shea, who was not a stockholder, joined as the fifth full-time employee. Although Walker was exerting the original stockholders to work even harder and to consider a full time commitment at Autodesk, he and Dan Drake were still involved in running Marinchip Systems and would be until late 1984.

It was also at this point in time that Autodesk realized that it was not the only game in town. Other companies were starting to release PC CAD packages. One package that particularly concerned Walker was CADplan, especially since it appeared that Sun-Flex was working with the package's developer, P-CAD. Sun-Flex was Autodesk's major distributor for AutoCAD at this point, responsible for about half the current volume, and Walker envisioned that this relationship could change if CADplan proved to be better accepted in the marketplace than AutoCAD. P-CAD was eventually acquired by CalComp and renamed CADVANCE. It is interesting to note that there are only a few minor references to VersaCAD in *The Autodesk Files* even though VersaCAD probably was a more significant competitive threat at the time.

### Spawning a publishing industry

Also in 1983, Lionel Johnston launched *CADalyst* magazine—the first magazine for AutoCAD users – from the kitchen of his home in Nelson, British Columbia. It began first as a newsletter for the AutoCAD User Group, then became the "journal" for AutoCAD users a year later. Autodesk helped fund the printing and distributed the magazine to all registered users until early 1986. Ad sales eventually enabled the magazine to become independent of Autodesk. In September 1987, David Cohn, who had been editing the Memphis User Group Newsletter, became editor of *CADalyst*.

In 1985, *Cadence* magazine was launched by David Baceski in Austin TX as the second AutoCAD magazine. It immediately became the arch-competitor to *CADalyst*, and subsequently launched a year-long legal battle during 1989-90 which ended in a draw when Baceski agreed to not pursue the lawsuit, and Johnston agreed to not counter-sue. In 1991, Johnston sold *CADalyst* to Aster Publishing for an estimated $3 million. Subsequently Aster was sold to Advanstar Communications and in 2004 the company acquired *Cadence* and merged it with *CADalyst*.

### 1984 – Explosive growth continues

Fiscal 1984[10] was the year many startup companies dream about and never have. From less than $15,000 in revenues in fiscal 1983, Autodesk's sales exploded to over $1 million and the company had a profit of over $100,000. With 1,000 copies of AutoCAD sold by the end of the fiscal year, it was well on its way to becoming the most popular

[9] Walker, John, *The Autodesk Files*, Pg. 166
[10] The company's fiscal year ends on January 31st.

CAD package the industry has ever seen. One result of this fast growth was that the company split its still privately-held stock 10:1 in July,1983.

Little did the world realize that this was the start of something huge, but they began to get an inkling when sales in fiscal 1984 exploded to 10,000 units. During that year, management spent a significant amount of time exploring several venture capital funding opportunities. None of them work out, however, and Autodesk continued to grow at a phenomenal rate using internally generated funds.

Perhaps the most significant management development in 1984 was the hiring of Alvar Green as chief financial officer. He would later become president and CEO as Walker relaxed his grip on the company. The company was still having problems achieving recognition from CAD industry professionals. Ed Forrest commented "To date: 4,895 systems installed. AutoCAD acts like real, grownup CAD. It isn't; but its great to practice on."[11]

The company ran its first four-color ad in *Scientific American* in September 1984. It is interesting to note that there is much less material in *The Autodesk File* covering 1984 than there is for earlier or subsequent years.

**Autodesk goes public**

Autodesk shifted into an even higher gear in 1985 as sales of AutoCAD grew to about 25,000 units and gross revenues increased to $27 million with profits of more than $6 million. The financial results were sufficiently impressive that the company had little trouble going public in June 1985. Autodesk raised a little more than $10 million by selling a million shares at $11 per share (the difference was the underwriting fees).

For the original stockholders, this was a return of $165 for each dollar they had invested. By the end of the year the stock was selling for $21 resulting in a number of new millionaires in Marin County. Based on subsequent stock splits, the initial offering price was the equivalent to $0.92 for today's stock and the end-of-year price was the equivalent to $1.75. Perhaps one of the most significant aspects of the company's IPO was that the company was able to reach the point where it could go public without having used any external venture capital funding. It is unlikely that many companies would try to do that today.

Product development also accelerated in 1985. In May, the company released AutoCAD 2.1, which was the first version to include three-dimensional capabilities. Version 2.15 included an external programming language based on LISP that was first called the "Variables and Expressions" feature. It was renamed AutoLISP in Version 2.18. At this point, AutoCAD consisted of over 100,000 line of C code. Its list price had increased to $2,000 plus $500 each for ADE-1 and ADE-2. ADE-1 supported complex dimensions, fillets, crosshatching, and architectural units. ADE-2 required ADE-1 and supported object snap, shape dragging, isometrics, and attributes. Users really needed both to do any complex drafting. A bi-directional translator to and from Intergraph's SIF format – called AutoLink – was also available from Autodesk for $10,000.

AutoCAD was supported on 31 different PCs. At that time, PCs were not as standardized as they are today and software vendors needed to test and certify their packages on each machine. Texas Instruments was now a major AutoCAD player. It

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[11] *A-E-C Automation Newsletter*, June 1984, Pg. 2

 

added AutoCAD to its own Professional Computer and sold the combined package for $10,000.

In May 1985, Autodesk combined ADE-1 and ADE-2 into a single package that had a suggested retail price of $1,000. At the same time, the company introduced ADE-3 that provided three dimensional visualization of wireframe and hidden line models, polylines (consisting of both line segments and arcs), interactive entity selection with highlighting and LISP enhancements. The suggested price for ADE-3 was $500. By the end of the year, AutoCAD was available in six different languages including Japanese.

Autodesk aggressively promoted AutoCAD 2.1 at the SYSTEMS-85 conference in Anaheim, California in June 1985 in both its own booth and in the booths of a number of partners. The company also showed prototypes of UNIX versions of the software running on Sun Microsystems and Apollo workstations. Although Autodesk would eventually support several different UNIX platforms, this never became a major part of the company's business and UNIX support was dropped with Release 13.

**Third party development – a key building block**

AutoLISP would eventually become the primary tool for developing specialized applications. Up to this point, most CAD systems were sold by vendors who provided all the applications they perceived their users wanted. As an example, there were no independent electrical schematic packages offered by third party firms that worked with Intergraph's IGDS CAD software. If users wanted to do electrical schematics, they purchased the application Intergraph offered. Autodesk changed the dynamics of how CAD applications were developed and marketed. In Version 2.5, AutoLISP allowed access to the DWG database. AutoLISP was based on XLISP, a public domain version of LISP written by David Betz. Betz later complained that Autodesk had failed to acknowledge the source, which the company later did.

Autodesk encouraged third-parties, many of whom were also part of its growing dealer network, to create applications in areas where Autodesk itself had limited expertise. AutoLISP was the key development tool for these organizations and within a few years there would be literally thousands of such applications and AutoCAD add-ons for everything from spell checking to specialized symbol libraries. Some of these firms, such as Softdesk, would eventually become significant business enterprises themselves.

When John Walker initially proposed LISP as an external AutoCAD programming language, he thought that it would be the first of a series of such development tools. Other languages he mentioned in a February, 1985 memo included FORTRAN, compiled BASIC, C and Pascal. He thought this could be done over the next 12 months.[12] It did not happen and it would be a number of years before additional external development tools for AutoCAD would be available.

The first significant AutoCAD application marketed directly by Autodesk was AE/CADD (later renamed AutoCAD AEC Architectural), which greatly improved users productivity in creating and modifying architectural drawings. It had been developed by Archsoft and was licensed by Autodesk for sale through its distribution channel. The package had an end user price of $1,000. This package began shipping in mid-1985.

The company also launched CAD/camera, a software package that would take a scanned raster image and convert it to an AutoCAD compatible vector file. At a time

[12] Walker, John, *The Autodesk Files*, Pg. 233

 

when most scanning solutions sold for as much as $100,000, CAD/camera was priced at $3,000 for the software alone. Users still needed to purchase a scanner or have the scanning performed by an outside service bureau. CAD/camera was never a particularly good or successful product. Eventually, Autodesk incorporated raster data directly into the AutoCAD data structure. At the launch of CAD/camera, Walker reportedly boasted that if the new product sold at least as many as copies as AutoCAD, they would become very rich. He possibly thought that CAD/camera would outsell AutoCAD.

Part of CAD/camera's failing was that it was primarily written by an outside organization that was not particularly responsive to Autodesk's requests for improvements. As a result of that experience, Autodesk took all crucial development in-house.

**Riddle and Autodesk part ways**

Within a few years, the relationship between Mike Riddle and Autodesk soured. According to Riddle, the non-exclusive terms of the original agreement were actually Walker's idea. Walker liked contractual simplicity and used as an example the page and a half contract Colgate Palmolive had for marketing Listerine. As mentioned earlier, Walker initially felt that Interact had fairly limited prospects. He most likely never expected the program to take off the way it did.

The original agreement was for a 10% royalty fee. What were nominal royalty amounts when just a few thousand copies of AutoCAD were sold annually became a fairly substantial amount of money as the volume increased. In the year ending January 1985, the royalty payments to Riddle amounted to nearly $600,000. One step Autodesk took to minimize the royalties owed Riddle was to consider many AutoCAD enhancements to be separate products. That was one of the primary reasons behind packages such as ADE-1 and ADE-2.

Autodesk tried to stop Riddle from marketing new versions of his software, called EasyCAD, which first became available in 1985. The new package was modeled after the Apple Macintosh and was intended to be very easy to install and learn – no classes and no consultants to support it. Legal actions initiated by Autodesk slowed the commercial momentum of EasyCAD and enabled under-$100 CAD products such as AutoSketch (written by Walker) and Generic CAD (later purchased and then killed off by Autodesk) to gain market share.

For several years, Autodesk reluctantly paid Riddle over $1 million per year in royalties. After an extended period of confrontation including a lawsuit filed by Riddle and his wife in August 1991, Riddle and Autodesk resolved the dispute in early 1992. In return for a payment of $11.9 million dollars, Riddle waived all future royalty payments. Considering that by that time there was only a minuscule amount of the original Interact code still in AutoCAD, this was probably a reasonable resolution for both parties.

**Autodesk continues rapid growth**

By early 1986, Autodesk was on a roll. One major reason for the company's early success was its reliance on a dealer network to sell AutoCAD on a worldwide basis. The company did not restrict the number of resellers in a given geographic area and as a consequence, there was substantial price competition between dealers to the point that many sold the software for little more than what they paid Autodesk. The expectation was that they would make their profit on hardware, training (there were 40 authorized AutoCAD training centers by late 1985) and post-sale support.

Many of the early dealers were users who liked the software and felt that they could make some incremental profit by acting as a reseller. In the process, they were able to acquire licenses for their own use at a substantial discount. For many years this model worked for both Autodesk and the dealers. In the early years, a key element of the reseller channel was also more than 1,000 computer stores, mostly ComputerLand and Entre locations. A number of computer manufacturers including Digital Equipment, Tandy, Texas Instruments and Wang Laboratories distributed AutoCAD although by fiscal 1986 this amounted to less than ten percent of the company's revenue.

AutoCAD was beginning to attract significant attention as it quickly became the low-cost standard. According to David Cohn, who was the editor of the Memphis User Group Newsletter at the time: "It has become the de facto standard much the same way dBase is the standard for database programs and Lotus 1-2-3 is the standard for spreadsheet programs."[13] There were over 50 local user groups in North America, many of which published newsletters or maintained on-line bulletin boards.

Mike Ford left the company in early 1986. With more than 200 employees, the company was beginning to show the signs of becoming a serious player in the computer software industry. It had four foreign subsidiaries in Switzerland, Sweden, England and Japan. Company officers at this point in time were:

- John Walker – president
- Dan Drake – vice president and secretary
- Al Green – vice president and CFO
- Keith Marcelius – vice president of research and development
- Richard Handyside – vice president of marketing and sales

Software Engineering was under Fred Hopperstead. Duff Kurland, one of the founders, handled most of the software documentation. Quality assurance was under another founder, Mauri Laitenen, although this was considered to be one of the company's problem areas. Product management was under Eric Lyons who had previously been at Auto-trol Technology.

David Kalish, also a founder, was responsible for coordinating third party software development. There were perhaps 200 third-party application programs available at the time. As the number of third party applications increased, Autodesk began publishing a catalog of them in April 1985.

Autodesk always pushed hard to have customers take problems to the dealer from whom they purchased the software. Bill Menser was in charge of product support taking on "the ultimate responsibility." Sandra Boulton headed up the company's marketing department while Bud Runnels was director of Autodesk's sales department and was handling major accounts while Richard Cuneo was director of dealer/distribution sales.[14]

Autodesk released AutoCAD 2.5 at A/E/C SYSTEMS in June 1986 with over 70 companies displaying AutoCAD-related products in their booths. The *Memphis Newsletter* was duly impressed.

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[13] Cohn, David, *Memphis User Group Newsletter*, March 1986
[14] Cohn, David, *Memphis User Group Newsletter*, May 1986

 

> "We are stating right here, categorically, that AutoCAD Version 2.5 is the new standard by which all other CAD packages will be judged." [15]

Autodesk showed AutoCAD running on Apollo, Sun and IBM (RT) workstations and they demonstrated 3D capabilities in the "Futures" portion of its booth. The company demonstrated AutoSHADE, which was capable of generating shaded images of two and a half dimensional models with availability expected in late 1986 at a price of $500. Autodesk also announced that it had placed its device driver development software (ADI) in the public domain. List price for AutoCAD with ADE-3 was $2,850.

The UNDO command was extended to undo just about anything one could do with AutoCAD including recapturing erased items. There was also a REDO command added to this release. With Version 2.5, colors and line types were now independent. Other enhancements included support of IGES 2.0, tracking of the time spent working on a given drawing, a DIVIDE command that enabled the user to divide an object into equal length parts, and the ability to explode a block into its basic elements for editing. Another new command was MEASURE. Overall, this release had 70 new commands.

The 1986 A/E/C SYSTEMS conference also saw the first National AutoCAD User Group meeting presided over by Sandra Boulton. David Cohn was one of three individuals representing user groups at the initial session attended by 120 users.

**Debate over hardware locks**

Version 2.5 was the first release of AutoCAD distributed in the United States and Canada that had a hardware lock. It was about the size of a pack of cigarettes and went on the COM1 port. This caused a storm of complaints from users especially since most other PC software companies were moving away from hardware locks at the same time Autodesk was introducing the technology. Some companies even began offering software that enabled users to run AutoCAD without the hardware lock installed. Their promotional material was very carefully worded to imply that the software should only be used for legally licensed software. Part of the problem was that some users were having problems running legal copies of AutoCAD due to configuration issues.

Before 1986 was over, Autodesk removed the hardware lock requirement for copies of AutoCAD sold in North America and distributed to all registered users a copy of AutoCAD 2.52 which did not require the lock. In the announcement concerning removal of the lock, Green was particularly upset over the negative reaction among users when, according to him, all Autodesk was doing was protecting its intellectual property. He stated that he was surprised users looked at the hardware lock as being an assault on their moral integrity and he pointed out that all the vendors of 32-bit engineering workstations incorporated some form of software protection. My analysis is that Autodesk was simply tired of the hassle and that it was probably starting to cost the company some business. A byproduct of this episode was that Autodesk became one of the strongest backers of the Business Software Alliance and its anti piracy campaigns. Autodesk has not been shy in suing companies who use illegal copies of its software and publicizing those cases.

**Changes in management and direction**

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[15] *Memphis Newsletter*, July 1986

Fiscal 1987 saw the company's revenue increase by nearly 78 percent to over $54 million while earnings grew by a similar amount to $11.6 million. During the following year the pace continued with revenues increasing to over $79 million and earnings to $20.6 million. Autodesk's stock continued to do well and the company initiated a three for one split in March 1987 and sold an additional 2,500,000 shares in June 1987 with net proceeds to the company of $57.4 million. In mid-1987 Autodesk was named the fastest growing small company for the second year in a row by *Business Week*.

In November 1986, Al Green became CEO, replacing John Walker who remained chairman of the board until June 1988. At that point, Green became chairman of the company although Walker remained a company employee, working on new software out of his home in Muir Beach, California rather than at Autodesk. At the time, there does not seem to have been much concern that a financial executive was taking over the reins of a high tech software firm, especially one with a very independent minded development staff. One other key management change was the hiring of Malcolm Davies in January 1988 as vice president of marketing and sales, a position similar to the one he had previously held at Calma. Version 2.6 began shipping in April 1987 with support for SUN, Digital Equipment and Apollo workstations as well as IBM compatible PCs running MS-DOS.

During 1987, several significant product and business developments occurred at Autodesk. Around mid-year, the company announced that it was working on a solids modeling enhancement to AutoCAD based on software the company had obtained when it acquired Cadetron several months earlier. Initially this software was called The Engineer Works but that name was subsequently changed to AutoSolid. Initial plans were to release the software on UNIX platforms first (probably because of performance issues) and then later on PCs. AutoSolid was a stand-alone product that initially sold for $5,000. Data could be transferred to AutoCAD for the production of detailed drawings.

Other new products were AutoCAD AEC Mechanical which facilitated designing plumbing and HVAC elements of buildings and AutoShade for full color rendering. AEC Mechanical was released in August 1987 while AutoShade was released a month later. Both sold for $500 per copy. Later that year the company introduced AutoFlix, a $35 enhancement to AutoShade that enabled users to create animated sequences of shaded models. The company also announced around mid-year that it had established a Federal Accounts Group.

Probably the most unusual development during this period was the company's $225,000 investment in External Tanks Corporation, located in Boulder, Colorado. This company, which was 80 percent owned by the 57-member University Consortium for Atmospheric Research, planned to reuse Space Shuttle external fuel tanks for orbiting research purposes or experiments utilizing the tanks upon reentry. The expectation was that this would be far less expensive than alternative facilities such as the International Space Station that was in the early stages of design. Autodesk thought this would be a good way of obtaining some publicity for the company and to possibly create a presence in the space program. Other than some detailed plans, nothing ever came of this initiative.

Autodesk introduced AutoCAD Release 9 in September 1987 with a new user interface that included pull down menus. The company's marketing people decided that this was really the ninth release of AutoCAD and decided to go to a whole number nomenclature rather than call it Release 2.7 or something similar. Data files were now fully portable between DOS and UNIX versions of AutoCAD, eliminating the need to use DXF transfers.

The MS-DOS version of Release 9 also required a floating point coprocessor. The new user interface could only be used with newer graphics cards such as CGA, EGA, VGA or Hercules. Meanwhile, Autodesk increased its focus on policing sellers of illegal copies of AutoCAD. Custom agents raided the Golden Shopping Center in Hong Kong and seized 200 illegal copies of AutoCAD.

By the end of 1987, Autodesk had sold nearly 150,000 copies of AutoCAD and there were more than 400 third party vendor products in the company's Applications Catalog. By this point there were over 1,300 resellers of AutoCAD including various computer stores in the United States and 150 dealers and distributors in foreign countries. There were also more than 200 authorized training centers worldwide. By April 1988, there were 48 books available describing various aspects of using AutoCAD. One of the more significant AutoCAD books was *Inside AutoCAD*, published by New Riders Publishing in 1985. By Mid-1989 more than 250,000 copies had been sold.[16]

In late 1987, Autodesk put together a plan to create a new product for the Apple Macintosh computer. The initial thinking was that it would not be possible to simply port AutoCAD to the Macintosh. The planned project was expected to take about a year and would have resulted in a two-dimension version of AutoSketch, but with many additional features. In early February 1988, John Walker personally began working on porting AutoCAD to the Macintosh II. Within two weeks, he had a demonstrable version working. The project to create a new program was soon dropped and a version of AutoCAD 10 ported to the Apple platform with some Macintosh-specific extensions was soon released.

Autodesk was different than most other software firms, perhaps because of its location in Sausalito. Employees frequently brought pets to work and it was an unpretentious operation. According to Sandra Boulton, director of marketing: "We still have folding chairs and used furniture. We still hold our beer busts on Friday nights. This doesn't look like a $50 million company."[17] For the first time, however, there were starting to be comments about AutoCAD's high price, at least as compared to other PC CAD software, and the fact that the software was falling behind technically. There were two areas where the latter was particularly true, three-dimensional modeling and the user interface.

In December 1987 the company promoted Chris Record, who had been general counsel and corporate secretary to the new position of vice president for corporate and business development. With $100 million in cash and short term investments, the company was getting ready to expand via acquisitions.

**Autodesk invests in Xanadu**

The first significant diversification away from AutoCAD and its related applications came in 1988 when Autodesk acquired an 80 percent interest in Xanadu Operating Company. Xanadu[18] was the dream of Theodor Holm Nelson, a software architect who had coined the term "hypertext" in the mid 1960s. Ted Nelson set out at the

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[16] Today, there are nearly 1,800 books about AutoCAD listed on Amazon.com.
[17] Freiberger, Paul and McNeill, Dan, "Autodesk's Lucky Strike," *PC World, December 1987*
[18] Xanadu was the elaborate palace in *Kubla Kahn*, a poem by Samuel Taylor Coleridge.

 

time to create a universal library and a worldwide hypertext publishing tool that would be accessible by anyone.

For the next 25 plus years, Nelson struggled to get someone to fund his grandiose ideas. For the most part, work on Xanadu was done by a small coterie of young hackers who fervently believed in Nelson's vision of changing how the world dealt with the growing flood of computerized information. Among these disciples were Roger Gregory, Michael McClary and Mark Miller. To quote Gary Wolf writing in *Wired Magazine,* "Xanadu was supposed to save the world."[19]

Nelson achieved a degree of fame among the more esoteric elements of the 1970's computer movement with his publishing of a 300,000 word treatise on the digital revolution called *Computer Lib/Dream Machines.* For the next decade, Xanadu's devotees attempted to actually implement Nelson's ideas without much success. They frequently had small parts of Xanadu's core software demonstrable, but anyone who delved into what they were doing soon became aware that managing the volume of data they envisioned was well beyond any computer systems then available or soon expected.

During these years, Nelson supported himself going between jobs in industry and teaching assignments. In 1981 he published a book, *Literary Machines*, that was a rambling discourse on the hypertext concept. He revised this book in 1987. About the same time, Gregory participated in a series of annual hackers conferences that were inspired by Steven Levy's book, *Hackers*. One of the other attendees at the 1987 conference was John Walker. He had heard of Xanadu and was well aware that it had never had the benefit of any serious software management.

After extended discussions with Gregory and Nelson, Walker saw Xanadu as a solution for managing engineering design data and agreed to have Autodesk invest in the company. With some foresight, he realized that Nelson was a creator of ideas but not someone to be involved in the actual development of the software and gave him a job in Sausalito as an Autodesk Distinguished Fellow while the Xanadu programming staff was set up 50 miles away in Palo Alto.

It seems that Walker and other Autodesk executives believed that the Xanadu programmers were farther along in creating a workable prototype than they actually were and when they announced the investment in Xanadu in April 1988, the statement was made that they would bring an initial system to market in 18 months. This was wildly optimistic and when Autodesk ceased funding Xanadu in 1992, there still was no functioning software. Someday, the World Wide Web and search engines such as Google may expand sufficiently to encompass many of the hypertext concepts Nelson expounded on for so many years.

**Autodesk without Walker at the helm**

There is no question but that John Walker was the driving force behind Autodesk's early success. He managed the company's money well, did not let the founders and early employees who were now millionaires loose sight of the fact that the company was vulnerable to competition by much larger firms including IBM and, for the most part, he kept everyone focused on AutoCAD, the company's crown jewel. The company he left behind probably needed someone at the helm with a better feel for the

[19] Wolf, Gary, "The Curse of Xanadu," http:www.wired.com/wired/archive/3.06/xanadu_pr.html

 

intricacies of running a large software firm than Al Green. This did not become obvious for some period of time.

Several management changes in mid-1988 were the promotion of David Kalish, one of the founders, to be director of strategic marketing and Cliff Gauntlett, formerly with Auto-trol Technology, to be manager of AEC technology. The company then acquired a majority interest in American Information Exchange Company (AMIX), a developer of software for information exchange between organizations. This was an unsuccessful forerunner of the Web-based exchanges that would pop up during the dot com boom of the late 1990s. AMIX also attempted to act as an intermediary for consultants who wanted to market their services.

AutoCAD Release 10 began shipping in October 1988. The older ADE-1, ADE-2 and ADE-3 options were no longer part of the company's product line. These capabilities were incorporated into AutoCAD itself, which now had a list price of $3,000. The upgrade cost from Release 9 was a moderate $250. Release 10 had substantially more effective three dimensional capabilities than earlier versions of AutoCAD.

Perhaps the key feature of Release 10 was the software's ability to display multiple non-overlapping views of a single three-dimensional model or different portions of a large drawing. Only one viewport could be active at a time and the user had to specify which view that was. AutoSolid Release 3 followed in early 1989 with enhanced capabilities for generating finite element meshes.

Indicative of the company's growing focus on three dimensional modeling and the mechanical CAD market in particular, Autodesk hired Ron McElhaney in October 1988. In February 1989 he became vice president of software development, replacing Keith Marcelius. McElhaney had previously been with Unicad, Graftek and Auto-trol Technology. He was president of Unicad from 1983 to 1987. Only three founders were still corporate officers – Dan Drake (who was executive vice president), Richard Handyside and Greg Lutz.

In 1988 the company changed how it sold AutoCAD to large accounts. Autodesk set up several sales offices in the United States and staffed them with major account sales people. Working with local dealers, the Autodesk account managers were able to offer Fortune 500 companies volume discounts, on-site training and applicable support. By the end of 1988, AutoCAD was being sold in more than 60 countries including a Russian language version in the Soviet Union. That made a total of 12 different language versions of the software. The number of third party software application now exceeded 700.

In April 1989, Autodesk announced plans to acquire one of its low-cost competitors, Generic Software, located in Bothell, Washington for approximately $7.6 million. This acquisition was completed the following month. The company's software products, sold as Generic CADD, were typically priced under $400.

**Life starts getting more complicated**

With Release 10, AutoCAD had become a significantly more complex computer program. With earlier versions of the software, users had been able to obtain a disk with patches from their local dealer or download the changes from CompuServe. Individual versions of the software started sporting nomenclature such as R10 c2a. With R10 c7, which fixed a large number of bugs and included an improved IGES translator, the process was nearly equivalent to an actual update from one release to another. The user had to return the serialized disk #1 for the version currently being used through an authorized dealer and then wait for a new set of diskettes (AutoCAD was not yet available on a CD-ROM) to be shipped from Autodesk. This whole process could take several weeks.

The suggested list price of AutoSolid was reduced from $5,000 to just $500 when Autodesk made public the fact that it was working on new solids modeling technology that would be incorporated directly in AutoCAD with Release 11 in second half of 1990.

The company indicated a growing interest in the multimedia market with the release of Autodesk Animator, a stand-alone package with paint and image processing tools. It was only available on PCs and sold for $395 per copy. At about the same time, Autodesk set up a new division to pursue this market called Autodesk Multimedia.

Animator was followed by a substantially more comprehensive program, Autodesk 3D Studio, which could be used to create three-dimensional models and render and animate these models. 3D Studio, which was developed by Gary Yost and the Yost Group and marketed by Autodesk, had far more sophisticated surface modeling than AutoCAD. It initially sold for $2,995. Libraries of clip art were available for sale that could be used with the multimedia packages. A separate dealer network was set up to handle these products. A new version of Autodesk Animator, Animator Pro, with higher screen resolution and enhanced imaging and animation capabilities was planned for release in mid-1992.

The company also began working on virtual reality research by funding an effort called the Cyberspace Project. This work in the company's Multimedia Division was managed by Randal Walser, who subsequently founded Spacetime Arts, a developer of virtual reality worlds. Walker was an important supporter of this activity in that he saw Autodesk software being used to create cyberspace environments. The company did release a Cyberspace Developers Toolkit but the project never resulted in products.

In another diversification away from AutoCAD, Autodesk introduced CA Lab (Cellular Automata Laboratory), a $60 package that could be used for tasks ranging from modeling fluid flow to simulating chemical reactions. It was programmed by John Walker with the help of one other programmer. A second scientific product was CHAOS: The Software, which was based on James Gleick's book *CHAOS – Making A New Science.* Apparently this package, which also sold for $60, was intended to help teach chaos theory. It seemed as if the company was beginning to worry that the market for AutoCAD was becoming saturated and that it had to look for new markets if it was to continue to grow. This would be a recurring theme for the next few years although it is hard to understand how anyone expected either of these programs to be a large revenue producer.

On the other hand, a agreement with Hypercube, Inc. for exclusive worldwide distribution rights to their molecular modeling software showed promise of being a significant endeavor. Computers were beginning to reach a level of performance where desktop molecular modeling for genetic engineering, drug and chemical research was a practical technology.

The key product was called HyperChem. It was a graphical front end and modeler. Other packages, HyperNewton and HyperNDO were used to make various molecular calculations. If marketed effectively, this software had the potential to generate substantial revenue in future years although not in the same league with AutoCAD.

 

Autodesk thought enough of this opportunity that the company acquired an equity interest in Hypercube.

In early 1990 Autodesk began shipping a version of AutoCAD Release 10 specifically tuned for use on 80386 machines equipped with Phar Lap's 386/DOS Extender. List price for this combination of software products that eliminated time-consuming program overlays was $3,300. Benchmark tests performed by Autodesk indicated a 30 percent to 62 percent improvement in performance.

With more and more users interested in producing shaded images of models they were creating, third party graphics accelerators were becoming increasingly important. For example, Nth Engine offered its Series 350 display processor for $3,395 with 1024 by 768 resolution and $3,995 for 1280 by 1024 resolution. Both graphics cards supported 16 colors.

**Autodesk starts a new decade**

By the end of fiscal 1990 the numbers describing Autodesk were becoming impressive – more than 900 employees, close to 300,000 copies of AutoCAD sold, 4,000 authorized dealers, 700 third party applications and 350 independent training centers worldwide. None of the company's founders were officers of the company at this point although Dan Drake and Greg Lutz were still on the board of directors. The company was doing so well financially, revenues of $179 million and earnings of $46.4 million, that it declared a special $1.50 per share dividend. When subsequently asked "Don't you have something better to do with your cash," Green's response was "Well, no we didn't."[20]

Autodesk announced in January 1990 that it would cease marketing AutoCAD AEC Mechanical and that the original developer, Archsoft Group (ASG), would assume responsibility for the package. In April, the company made a similar announcement regarding AutoCAD AEC Architectural although, in this case, the company's U.K. subsidiary continued distributing a metric version of the software.

Also in April 1990, Autodesk licensed the ACIS geometric modeling kernel from Spatial Technology. The company signed several other licenses in 1990 for advanced technology including NURBS surface geometry from Applied Geometry Corporation, graphics software from Ithaca Software and constraint management software from D-CUBED, Ltd. At the time, it was not clear the extent these software components would be incorporated into future releases of AutoCAD or if they would be used for a new product(s).

On October 18, 1990, Autodesk began shipping AutoCAD Release 11 priced at $3,500. The marketing manager for this release was Greg Milliken, who, after stops at several other companies, eventually became CEO of Alibre as discussed in Chapter 21. Release 11 incorporated a new AutoCAD Development System (ADS), multi-view plotting, network support, Advanced Modeling Extension (AME) which was sold as a $495 option, a new drawing recovery command and reference drawings (Externally Referenced Blocks or Xrefs) as well as improvements in the user interface.

AME was based on the PADL-2 solids modeling software developed at the University of Rochester. See Chapter 2. It used both constructive solid geometry (CSG) and boundary representation techniques. Release 11 also introduced the terms Model

[20] Zachary, G. Pascal, "'Theocracy of Hackers' Rules Autodesk, Inc., A Strangely Run Company," *Wall Street Journal*, May 28, 1992

 

Space and Paper Space for composing drawings and plots. Extensive enhancements to AutoLISP and the AutoCAD Development System (ADS) were included in the release with the expectation that these tools would enable third party developers to create more sophisticated AutoCAD applications. Overall, it was a substantial update but to many observers, including John Walker, it was simply an unsuccessful attempt to catch up to the more powerful systems being sold by the traditional turnkey vendors. The company planned to support all current platforms with some exceptions regarding ADS and AME.

Dr. Joel Orr, who had been appointed an Autodesk Distinguished Fellow, was the keynote speaker at the first North American AutoCAD User Group (NAAUG) meeting held in August 1990 in San Jose, California. When Autodesk started establishing NAAUG earlier in the year, John McQuary was selected as its first president. The meeting attracted 634 attendees who approved the organization's bylaws and elected Phil Kreiger to represent local user groups and Jay Reinhardt as the president elect.

Prior to this event, the only way AutoCAD users could communicate with Autodesk to express their grievances or to make product suggestions was through their dealers or via a CompuServe bulletin board. This organization would have a significant impact on Autodesk's product direction in coming years. John Forbes led off the day and a half meeting with an introduction to Release 11 followed by a demonstration of the new software by Tom Kopinski, the software's product manager. The NAAUG meeting was followed by the annual CAD Camp held for dealers.

Release 11 began shipping in October 1990, two years after Release 10. It would be another two years before users saw another release of AutoCAD. One significant change Autodesk made with Release 11 was that it established a Strategic Developers Program and provided these partners with pre-release versions of the software. That enabled them to release products such as DCA Software's civil engineering package in parallel with the shipment of Release 11. In April 1991, DCA would change its name to Softdesk.

Equally important was that graphics hardware manufacturers such as Nth Graphics were able to ship driver upgrades in a timely manner. High performance graphics cards were becoming increasingly important to users who were doing more and more visualization. Nth Graphics was offering the Nth Engine/150 with 1280 by 1024 resolution for just $2,000.

**Information Letter #14**

Fiscal 1991 saw revenues increase by 33 percent to $238 million with net income of $56.8 million. AutoCAD represented 88 percent of the company's revenue. Autodesk now had nearly $150 million in cash and marketable securities. With results such as this, it was hard to believe that this was actually a company in trouble.

In January 1991, Autodesk released AutoShadeVersion 2 which included RenderMan for enhanced rendering of AutoCAD images, priced at $1,000 per copy. Autodesk licensed RenderMan software from Pixar Animation Studios. A version without the RenderMan software was available for $500.

In November 1990 Walker took a few months off to relax, read and think about the future of Autodesk. The result was Information Letter #14. An early version was circulated to several senior managers at the company, one of whom, unfortunately, allowed it to gain wider than intended distribution. Walker quickly finalized the document and Information Letter #14 was delivered to the company's senior management on April 1, 1991.

Walker's primary concern was that Autodesk had been so successful that it had become complacent. His concern was:

> "…most companies that attain great value then lose it do so by *failing* to adapt when technological progress or the market demand they change."

He went on to apply this thought to Autodesk.

> "When a company ceases to change at the rate demanded by the industry it exists within, it finds itself rapidly left behind. Before long, its customers discover products of competitors that better meet their needs. As market share slips, sales fall, and earnings decline, the management of the standstill company asks, 'What's happening? We're still doing all the things we used to do.'……. Autodesk possesses all the prerequisites to lead the next generation of the PC industry, yet it seems to have become stuck in the past, mired in bureaucracy, paralysed (sic) by unwarranted caution, and to have lost the edge of rapid and responsive product development and aggressive marketing and promotion on which the success of AutoCAD was founded. Not only has Autodesk failed to bring the new products it needs to the market, it is allowing AutoCAD, our flagship product and the source of essentially all our revenue, to become dangerously antiquated and under-marketed to an extent that is virtually unique for a product generating sales in excess of $200 million a year."[21]

Walker explicitly stated that he did not want what he was writing to imply that he wanted the company's current management removed nor did he want to resume a full-time management roll. Rather, he was writing this document in an attempt to get them to act decisively in regard the issue he felt were key. Information letter #14 was a 44 page treatise. Space allows just some of its highlights to be listed.

- AutoCAD was the company's key product but was not receiving sufficient development and marketing attention or resources.
- While Autodesk focused on AutoCAD's basic capabilities it was ignoring ancillary capabilities that Walker believed customer expected given the price the company was charging.
- AutoCAD's user interface was not keeping up with the state-of-the-art.
- AutoCAD was expensive compared to other PC software products.
- Computer stores were going out of business leaving dealers as the company's primary distribution channel. Walker questioned whether these dealers could prosper selling AutoCAD at a nominal markup and if Autodesk should move to a mass marketing model.
- Microsoft's Windows operating system (3.0 was the current version) was a "Big Event" and Autodesk was not paying sufficient attention.

[21] Walker, John, "Information Letter #14"

- Walker stated: “I believe that a CAD product with these characteristics: big, cheap, widely available, tightly integrated with its host system, and promoted and marketed in an aggressive manner could, in relatively short order, displace AutoCAD from its current dominance of the CAD market.” Autodesk could either produce this product or watch someone else do it.
- Release schedules were being dictated by financial concerns.
- Once a new product was introduced, Autodesk spent an inadequate amount of money marketing it. Walker was particularly incensed by the low key way the company launched AME, the solid modeling extension introduced with Release 11.
- What the company needed was a better balance between imagination and caution.

A key section of this document was what Walker called The Nightmare Scenario. In it he fictionalized how Bill Gates would become enamored with the money Autodesk was making off AutoCAD and would launch “Windows Engineer”, an $895 CAD package built predominately with component technology and launched with a massive advertising campaign. Since Microsoft probably saw this memorandum shortly after it was distributed internally at Autodesk, one has to wonder why Gates didn’t take Walker up on his suggestion. Like any good manager, Walker did not simply itemize what was wrong with Autodesk. He concluded this document with a list of specific recommendations, most of which make sense looking back more than 15 years later.

- Appoint strong project managers for each Autodesk product and have them report to the president (I agree with the first but question whether someone responsible for a low-volume product such CA Lab should work directly for the CEO).
- Implement product-level profit and loss accounting.
- Help the dealers be successful (This is an issue that would plague Autodesk for years to come).
- Reduce product prices, especially for AutoCAD in order to grow volume.
- Treat industry opinion leaders better including providing them free software products.
- Incorporate AME into AutoCAD and promote solids modeling aggressively.
- Jump on the Windows bandwagon.
- Upgrade AutoCAD documentation.
- Let customers contact Autodesk directly for support rather than requiring them go through a dealer.
- Assign more personnel to product development.
- Aggressively go after the raster (multimedia) market.
- Start work on an entirely new CAD system to eventually replace AutoCAD.

 

Reading Information Letter #14 is like participating in a case study at a well-respected business school. Walker comes through as a much more multi-dimensional individual than he appeared to be earlier in his career. As idiosyncratic as he might be, no one can deny that this guy was bright, perhaps even brilliant. A month after the letter was distributed, Walker moved to Marin, in the canton of Neuchâtel, Switzerland to join Kern Sibbald, another company founder, in establishing Autodesk's European Technology Centre.

**Reaction to Information Letter #14**

Although Information Letter #14 was intended for "senior management" and was considered company proprietary, within hours everyone in the company had heard about it and copies were in the hands of people outside the company. In spite of his statement that he did not intend to rejoin the company's management team the reaction of many employees was that "Walker is back."

Ron McElhaney left Autodesk in September 1990 and was replaced as vice president of research and development in early 1991 by Marc Stiegler who had been general manager of Xanadu for several years. Stiegler had had a successful software career, retired early, became a science fiction writer and then joined Xanadu in 1988 to try and bring some semblance of order to the organization. Interestingly, Stiegler rather than Al Green became the architect of a new Autodesk organizational structure in June 1991, or at least the one who publicized it. In fact, Green seemed to be all but invisible while the debate over Autodesk's future was going on.

The corporate reorganization in June1991 was intended to separate the company's activities into product development and marketing on one hand and service and corporate-wide activities on the other hand. Products were tentatively separated into several different groups – AutoCAD, Multimedia, Retail, Molecular Modeling and Information – with a general manager responsible for each product family and a product manager responsible for each specific product. In some cases, the general manager could also be a product manager. Stiegler distributed these ideas in a memo titled "The New Autodesk."

Walker's reaction was that this structure was better than what existed previously even if it was overly detailed but that it had a critical flaw in that sales did not report to the general manager of a product family. His concern was that emerging products would not get adequate sales attention since it was much easier for the sales force to simply promote AutoCAD. The other flaw he saw in this structure was that AutoCAD represented nearly 90 percent of the company's revenue. It would be hard to treat the product manager for AutoSketch the same as the product manager for AutoCAD.

Walker was also upset that this reorganization appeared to be the company's entire response to Information Letter #14. In fact he points out on his web site that the number of programmers assigned to AutoCAD actually dropped after the letter was published. On June 18$^{th}$ and 19$^{th}$ he responded to Stiegler in two emails as only John Walker could.

> "I think there's a risk that the reorganisation (sic) plan will be viewed by many as exalting minute details of management structure over directly addressing the genuine problems of the company and its products. I share

 

this worry myself. First, when the IL14 bomb burst, I believe and I said at the time that management missed a truly golden opportunity to turn around the morale of the company. I think that by appearing defensive and reactive rather than aggressively seizing the initiative, the perception of the very problems I outlined in the letter was reinforced."

He went on to say that Green had to step up to the plate and tell the company's employees what Autodesk's strategy and vision was and if Green was unwilling to do it then Malcolm Davies, as executive vice president, should do it. Walker went on to tell Stiegler that the reorganization was only one part of what he wanted to see happen and that improving internal morale and allocating development resources more effectively were equally important. He ended the second email with:

"Whether you have in me an enthusiastic contributor or the worst nightmare a corporate management can have: an articulate, wealthy, major shareholder acting in the interests of the other shareholders and in keeping with the goals for which he founded the company, asking of management in public simple questions for which they have no answers, will be decided in the near future."

One positive result of the reorganization was that about 60 people, half of them programmers, were added to the AutoCAD team. It is interesting to note that on June 18, 1991 Autodesk's stock hit $61 per share. Eight months later, as the company tried to find direction, the price dropped to $23.50.[22]

**The struggle to find direction**

Walker, whose official position was simply that of a programmer in the company's European Technical Center, was becoming more and more frustrated with the direction Autodesk was taking. He felt that the company had to more aggressively develop and promote AutoCAD while at the same time create new products that would continue and even accelerate Autodesk's rapid growth. He did not see this happening and came to the conclusion that it was caused by a lack of effective executive management. It was clear that he felt Al Green had to go but he also was fairly negative in his comments about Malcolm Davies.

On September 26, 1991, Walker distributed a memo to "… a very short list of people whose discretion and judgement(sic) I trusted entirely."[23] One can probably assume that this included some of Autodesk's original founders who still worked for the company. In the memo, Walker flatly stated that there had to be a change at the top. He simply felt that the current management did not have either the vision or the ability to lead the company in the future.

Walker went to describe a meeting that he had held earlier in 1991 with Dr. Joel Orr who wrote the foreword to this book and was a consultant to Autodesk at the time.

"I don't think Autodesk's executives know very much about the CAD business. Frankly I don't think they're very interested in it. Joel Orr put it

[22] The stock has subsequently split three times and one share in 1991 is now the equivalent to eight shares.
[23] Walker, John, *The Autodesk File* – online version

 

> like this, as best as I can recall, when I met with him recently, 'When I talk to the people in Sausalito about what's going on in the industry, it's as if they're hearing these things from me for the first time.' It was abundantly clear from our discussion that this situation is unique to Autodesk, at least among companies he deems successful. Joel does not encounter this ignorance within the management teams of the many other CAD and computer graphics firms with whom he meets in the course of his consulting practice."

Although Walker is adamant that he did not initiate it, shortly after the memo recommending a change at the top was distributed, Green contacted him and said that he intended to retire and planned to initiate a search for a new CEO. This decision was announced on October 10, 1991. Green's plan was to have a new CEO in place during the first half of 1992 and that he would remain CEO until that occurred and then would become chairman of the board. In spite of what he may have thought about Green's vision and leadership, Walker distributed an email to the entire Autodesk staff graciously complimenting Green on what he had accomplished during his time as CEO.

The last quarter of fiscal 1991, ending January 30, 1991, had resulted in earnings that were barely ahead of the same quarter a year earlier, causing the company's stock to plunge 22 percent. Many people tried to shake it off due to external events including the war in the Middle East. Walker's concern, as discussed above, was that the company was cutting back on product development and marketing in order to make its numbers during the first three quarters of the subsequent fiscal year. For the first three quarters of fiscal 1992, the financial side of the business seemed to be going according to plan. This was not to continue however.

In January 1992, Walker returned to Sausalito for three months as "manager of technology." Since moving to Switzerland, if he returned for a longer period of time he would have been subject to increased U.S. Taxes. Shortly after arriving he was informed that the fourth quarter of fiscal 1992 was going to be a financial disaster with earnings down to a level not seen in three years. On January 30th the company held a meeting for major shareholders and security analysts in New York at which time Walker made two presentations. The first was a history of the company and the second, a description of products the company would release during the next 12 months including AutoCAD Release 11 for Windows during the first quarter.

Walker's two presentations were sandwiched around a financial presentation made by Green. The New York meeting was followed by a similar meeting in Boston the next day. While revenue for the quarter was estimated to be between $64 and $66 million or up slightly from the year before, earnings were down 39 percent to about $8 million. This was about half what some analysts were expecting.

The stock market's reaction was nearly as negative as it had been a year before. This time the stock dropped 18 percent to $28.25 per share or less than half what it had been six months earlier. Two days later Walker and Green repeated the talk on a Saturday afternoon for nearly 700 Sausalito employees. With Walker taking such an active role in these two meetings, it would was not hard to see where many employees hoped that he would return as CEO. It was not to happen.

 

One positive development was the launch in March 1992 of AutoCAD Extension for Windows. For $99 per copy AutoCAD users could upgrade their current Release 11 licenses to run under Windows. For the next several years there would be a constant debate between the proponents of the DOS version of AutoCAD and the Windows believers. The two major issues were existing familiarity with DOS and relative performance as the DOS versions tended to be faster for some period of time.

At this point in time, management of the AutoCAD product line was being shared by Ruth Connolly who was the AutoCAD general manager and John Lynch, a bright, thoughtful software professional, who was the AutoCAD chief technical officer. Lynch had joined Autodesk in 1986 as a programmer. Shortly after shipping AutoCAD Extension for Windows, Autodesk began shipping HyperChem.

In an interview with Mary Eisenhart of *Micro Times*, Walker summed up Autodesk's position and market philosophy very well:

> "That's what really happened with Autodesk in competing with the major mainframe CAD vendors for the drafting market. We didn't really take seats away from them--most of the companies that had those mainframe systems still have them, in fact have more of them. What happened was, we created an entirely new market for CAD that was the other 98% of the business they weren't selling to, and that's where the growth came from…….In the *really* long term there isn't going to be drafting. But I think getting rid of it is going to take a lot longer than a lot of people believe."[24]

At some point in early 1992 Green relinquished day-to-day operations of the company and Volker Kleinn had temporarily taken on the responsibilities of chief operating officer. The company officers just before the new CEO took over were:

- Al Green – chairman of the board, president and CEO
- Malcolm Davies – senior vice president, the Americas
- Volker Kleinn – senior vice president, Europe
- Richard Cuneo – vice president, U.S. sales
- Carolyn Aver – vice president and CFO
- Sandra Marin – vice president, secretary and general counsel

**The Bartz era begins**

Carol Bartz is the pro-typical computer industry executive. With a degree in computer science from the University of Wisconsin in 1971, she initially worked for Digital Equipment Corporation and 3M Corporation before joining Sun Microsystems in 1983 in a relatively minor marketing role. Within a year, she was vice president of marketing and then built a successful government systems operation. In 1990, she was named vice president for world-wide operations with over 6,000 people reporting to her. At the time, she was one of the most senior woman executives in the computer industry.

[24] Walker, John, *The Autodesk File*

 

With a relatively young Scott McNealy running the company, there was little chance that her desire to run a major business enterprise would be met by staying at Sun.

Bartz was the first woman to become CEO of a major computer company that she had not founded. On April 14, 1992 she became president, chairman of the board and CEO at Autodesk. Al Green's plan to stay on as a non-executive chairman was shelved as part of the negotiations with Bartz concerning her responsibilities. Walker gave a short talk at an employee meeting introducing Bartz and said she had his full support. Two days later he headed back to Switzerland and fundamentally let her run the company without his interference. He left the company permanently with minimal fanfare in 1994.

Figure 8.2
Carol Bartz circa 1996

At A/E/C SYSTEMS '92, held in Dallas that June, Bartz stated that among the reasons for taking the job at Autodesk was her belief that the future of the computer industry would revolve around software rather than hardware. She felt that Microsoft was not the only successful business model, that Autodesk was well placed to succeed, was well financed (almost $200 million in the bank) and that she liked the informality of the company's day-to-day operation. At several meetings with the media she described plans to broaden the functional capabilities of AutoCAD as well as improve its performance.

It was clear that third-party software vendors who added functional capabilities to AutoCAD would gradually see those functions added to the basic AutoCAD product while vendors of more complex applications such as process plant or highway design probably did not have to be concerned that Autodesk would end up as their primary competitor in the near future. In particular, she indicated a strong interest in moving more aggressively in the mechanical CAD area.

Bartz started having an impact on the Autodesk organization almost at once. Malcolm Davies, who had contended for the CEO job left the company shortly after she took over. In a personal conversation she indicated to me that she was not at all unhappy to see him go. New people were arriving at a rapid pace. Len Rand, who had been with Intergraph until 1990, came on board as vice president of the AutoCAD division. Eric Herr, who had worked for Bartz at Sun, was hired to be vice president and CFO.

 

A few days after the conference, Autodesk announced that Bartz was suffering from breast cancer. My two older sisters were loosing that battle at the time and I was very understanding as she successfully battled back from the disease while effectively running the company.

**The Wall Street Journal article**

On May 28, 1992, just six weeks after Bartz took over, *The Wall Street Journal* printed an article about Autodesk on its front page. Written by G. Pascal Zachary, its title, "Tech Shop 'Theocracy of Hackers' Rules Autodesk Inc., A Strangely Run Company – Can the Latest CEO Survive a Cabal of Programmers Who Send 'Flame Mail'?" clearly indicated at the start that this was going to be a very unflattering article. Zachary's main points were that Autodesk was run by a group of programmers called the "Core," that there was constant conflict between these programmers and management, Green was ill-suited to run the company and that Walker was pulling the strings. The article was particularly harsh in regards to Walker.

Zachary had started work on this article months earlier and after interviewing Green by telephone, requested an in-person interview with Walker. Walker was not happy with earlier work of Zachary's that he had seen and set some strange requirements for the interview to which Zachary agreed. Among these was that the interview would be videotaped and that Autodesk held the copyright to the interview which was held on February 10, 1992. There were six other Autodesk people in the room along with Walker, but he handled most of the interview.

It is obvious from the interview transcript that Zachary had not done his homework and was unfamiliar with many aspects of the company. For example, he did not realize that Walker had not been on the company's board of directors for nearly four years. On the other hand, Walker was argumentative throughout the interview and was less than candid in discussing the intent of Information Letter #14 or its impact on the company. The entire interview transcript is posted on Walker's web site.[25]

What surprised me the most about the interview were some of the statements Walker made concerning Autodesk's technical position in the CAD industry. In one case when discussing the work he had done on AME in mid-1989 he stated: "Nobody else had ever, essentially, included solid modeling as an integral part of a CAD system." Hadn't he heard about a company called Parametric Technology that had begun shipping Pro/ENGINEER a year earlier? At another point when discussing automated manufacturing he said: "I don't see anybody else even working on it right now."

In a subsequent entry on his web site Walker responded to Zachary's famous statement about the cabal of programmers who ran the company. According to Zachary:

> "But the real power still rested with Mr. Walker, Autodesk's biggest shareholder, and an elite group of programmers called ``Core," who had either helped Mr. Walker found the company in 1982 or led its most important projects.
>
> Core members are contentious, eccentric, free-thinkers who have had a way of devouring professional managers."[26]

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[25] http://www.fourmilab.ch/autofile

[26] Zachary, G. Pascal, "Tech Shop" – *The Wall Street Journal*, May 28, 1992, Pg. 1

 

Walker was adamant that there was no group of programmers at Autodesk called "Core." He figured that what Zachary was referring was the small group of about ten programmers who work on the central components of AutoCAD rather than device drivers, applications or documentation. While this group included three founders: Duff Kurland, Dan Drake, and Greg Lutz, it had been managed since 1985 by professional technical managers hired from the outside. Walker was also upset that Zachary described Mike Riddle as an "outside programmer" rather than as a founder.

In reality, Bartz had her hands full gaining control over an unruly group of programmers, especially in regards to meeting deadlines. When she took over, work on Release 13 was already underway. The issue the new CEO faced was balancing the functionality of this next release with the need to get something out on schedule.

No one likes to have their feet held to the fire, especially by a new boss who they did not really know. Walker was one of them. Bartz came from a hardware company and how could she understand what programmers go through creating great functionality then to have it shelved in order to meet what they felt was an artificial delivery deadline. It took several years, but eventually she did gain the upper hand.

**Release 12 fills some gaps**

Autodesk used the A/E/C SYSTEM '92 Conference to showcase AutoCAD Release 12. Some of its key features included a new user interface with pull-down menus and dialog boxes, improved performance when executing pan and zoom operations, a much faster hidden line process, identification points on entities called "grips" that enabled the size, location or shape of these entities to be changed in a single operation and direct image shading in AutoCAD. To AutoCAD users these enhancement (there were 174 in all) were significant and Release 12 was enthusiastically received.

The reality was that AutoCAD still lagged behind many competitive CAD solutions on a functional and performance basis. Release 12 was an effort to catch up, but coming nearly two years after Release 11, it illustrated some of the problems Walker had been pointing out in his internal memos. The new list price for AutoCAD was set at $3,750 with the cost to upgrade from earlier releases $500. The DOS version began shipping in July 1992. Foreign language and some UNIX versions continued to lag however. As an example, the UNIX version of Release 11 for the IBM RS/6000 began shipping about the same time that the company was beginning to ship the UNIX version of Release 12 for the Sun platform. The Windows version of Release 12 lagged considerably behind the DOS implementation mainly because of performance concerns. It was eventually released in February 1993.

**Vermont Microsystems lawsuit**

One byproduct of the Release 12 Windows activity was a lawsuit filed by Vermont Microsystems Incorporated (VMI). This company had developed several display list software packages called AutoMate and AutoMate/Pro that improved display performance considerably, especially in regards to the Windows implementation of Release 11.

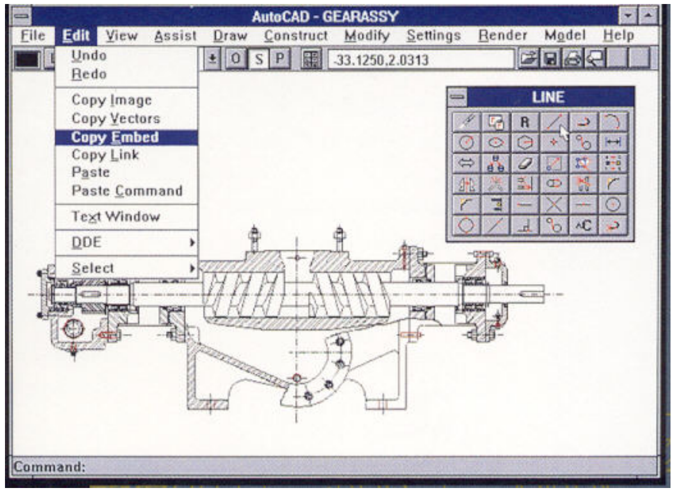


Figure 8.3
AutoCAD Release 12 for Windows[27]

One of the developers of AutoMate was a programmer named Otto Berkes who was hired by Autodesk in October 1991. When he left VMI he was warned that the work he had done for that company was proprietary and that he was not to disclose any trade secrets to Autodesk. In spite of this warning and warnings to Autodesk management, Berkes did end up working on the display list software incorporated in the Windows implementation of Release 12 using techniques he had first developed at VMI.

VMI sued Autodesk and won its case in December 1994 and was awarded $25.5 million while Autodesk was allowed to continue using the code. After several appeals, this was reduced to $7.8 million plus interest in February 1998 which Autodesk subsequently paid. Berkes ended up going to work for Microsoft where he was involved in the early development of the Xbox game system.

By mid-July the company's stock price had edged back up to $39 and investment companies including Goldman Sachs were recommending purchase of the stock. The increasing size of the AutoCAD installed base and the higher upgrade price were expected to provide over $12 million in upgrade revenues over the next six quarters. A large number of users (62 percent) were still using Release 10 or earlier versions of AutoCAD. Autodesk was also benefiting from the new higher performance Intel 486-based PCs that were available at attractive prices due to price competition among the PC vendors.

**Bartz takes charge**

During her first months as CEO, Bartz continued to build her management team. She added Steve McMann as vice president of human resources and Jackie

[27] Autodesk AutoCAD Release 12 for Windows brochure, October 1993

 

Rae as vice president of corporate marketing. Eric Herr was given the additional responsibility of vice president of emerging technologies with the task of overseeing the retail, multimedia and scientific modeling product lines. Autodesk also hired Dominic Gallello, the former head of Intergraph Japan, to head sales in the Asia/Pacific area and Godfrey Sullivan to do the same in the Americas. Some people said this was the first professional management team the company had, but this was probably unfair to those who preceded them.

Perhaps the most significant issue Bartz and her new team had to consider was whether AutoCAD and the CAD market overall had sufficient potential that this was where the company should focus the bulk of its resources or if this market was close to saturation and the company should plunge into new areas of software development. The decision was that the CAD market still had substantial potential and the company should focus its resources on AutoCAD and related products.

The first significant indication of this renewed focus on the CAD market was the announcement on August 20, 1992 that the company would cease funding Xanadu and AMIX after a 30-day grace period.[28] This basically spelled the death knell for Xanadu although remnants of the project hung on for over two years. Bartz was fairly blunt in announcing the change:

> "The new management team has carefully looked at what Autodesk's business model should be. Both AMIX and Xanadu are important companies with exciting futures, but they do not fit into Autodesk's core business."[29]

Mark Stiegler chose to leave Autodesk and briefly joined Xanadu and AMIX. After a few months, he left those companies and retired to a ranch in Arizona. Xanadu never proceeded beyond the vaporware stage but AMIX did hold some real promise. It was wine before its time, however, in that implementing AMIX exchange technology in the late 1980s and early 1990s involved writing a lot of code that simply was not necessary once the World Wide Web was up and running along with virtually free Web browsers.

The next major step Bartz took was the acquisition of Micro Engineering Solutions, Inc. for slightly less than $15 million. Located in Novi, Michigan, MES was the developer of SOLTUION 3000, a suite of design and NC software packages that used NURBS-based surface modeling. The company's two leading products at the time were called Design Expert and Manufacturing Expert. The bulk of the users of this software were in the automotive industry. Bartz had indicated earlier that she saw the mechanical segment of the CAD market being a major opportunity for Autodesk and this appeared to be the first step in that direction. The company's founder, Ken Spenser, agreed to stay with Autodesk and run the 50-person organization which was called the Autodesk Mechanical Division. The acquisition of MES also indicated that plans to extend AME by

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[28] Dr. Joel Orr who wrote the forward for this book served as chairman of the board at Xanadu after Autodesk spun it off.

[29] Autodesk Press Release, August 20, 1992

 

adding the ACIS geometric kernel were put on hold although the company stated at the time that AME would stay in the product line.

The company also considered several areas where it might broaden its software product line. It introduced a diagramming package called Actrix that competed with similar software from Visio and Autodesk even acquired a presentation package from a company in Sweden that enabled it to compete with Microsoft's PowerPoint software. Neither of these were particularly successful but they did cause some distraction as Bartz was trying to get the company turned around.

As 1992 progressed, Autodesk seemed to be regaining some of its earlier momentum. Revenues in the quarter that ended October 31, 1992 were up 33 percent to nearly $94 million although earnings dropped as the company worked on expanding its internal infrastructure. The major task facing Autodesk as 1992 drew to a close was completing the development of AutoCAD Release 13 which involved a major restructuring of the software package's basic architecture. It was a necessary step if Autodesk were to compete on even terms with the high-end CAD vendors in the future but it would turn out to be a problem-filled release.

**The new Autodesk starts to evolve**

In February 1993, Autodesk introduced several products that indicated the general direction the company intended to take. The Mechanical Division launched two new software packages based upon the technology obtained when the company acquired MES the previous year. Autodesk DesignExpert incorporated NURBS-based Auto-Surf, AutoCAD Release 12 and an IGES translator for a list price of $7,750. Autodesk Manufacturing Expert included the same suite of software plus 2- to 5-axis NC software for $13,750.

For the first time, Autodesk offered a software maintenance agreement for these packages. The expectation was with the next release of AutoCAD these mechanical packages would eliminate the need to use IGES to move data between programs. Other than the AutoCAD portion, the products consisted mostly of MES software with an Autodesk label on it. The company subsequently decided to focus on design software and the NC applications were sold to CAMAX Manufacturing Technologies in August 1994. CAMAX was subsequently acquired by SDRC in 1996.

The other new product was AutoCAD Release 12 for Windows. This was done much better than the earlier Release 11 Extension for Windows in that performance was better and the software used Microsoft tools such as OLE (Object Linking and Embedding) to move data between AutoCAD and Windows programs such as Word.

**Changing Autodesk's competitive posture**

Later in the spring Autodesk announced that the Retail Products Division would become part of the Design Automation Group headed by Len Rand. The company was also becoming more competitive in regards to other companies in the CAD industry. As described in Chapter 13, IBM and Dassault were struggling with customer transition from CADAM to CATIA and everyone wanted a piece of the CADAM installed base.

Working with Integrated Industrial Information of Raleigh, North Carolina, Autodesk introduced two packages aimed at these CADAM users. The first, Aemulus, provided a CADAM-like front end for AutoCAD while the second, $Aemulus_{mf}$ was a mainframe tool that provided bidirectional data file access between CADAM and AutoCAD. These had to be two of the worst product names in the history of the CAD industry. About this same time, Autodesk confirmed that it planned to use Spatial Technology's ACIS geometric kernel in upcoming versions of AutoCAD as well as Ithaca Software's HOOPS graphics software. The latter was not a surprise since Autodesk owned 20 percent of Ithaca. Autodesk eventually acquired Ithaca Software in 1993 and then spun it off as Tech Soft America in 1996.

Len Rand, who had joined Autodesk about the same time Carol Bartz was hired, quietly left the company in late July perhaps as a result of John Lynch taking on more of the Design Automation Group's development responsibilities. According to David Cohn: "The heralded arrival of Len Rand as Vice President of the newly formed Design Automation Group was far different from the silence surrounding his departure."[30]

From a business point of view, the big news in the fall of 1993 was the Navy's splitting the $550 million NAVFAC portion of its CAD 2 procurement between Intergraph and Cordant, the latter acting as a system integrator for Autodesk. As described in Chapter 14, this procurement had dragged on for more than seven years. The contract resulted in substantial business for Autodesk, especially within the Navy and the architecture and engineering firms working for various government agencies.

**AutoCAD LT ignites controversy**

For several years, the AutoCAD user group had met in the summer in conjunction with the company's CAD Camp, held for dealers and developers. In October 1993, the user group held its first meeting separate from CAD Camp. Now called Autodesk University, it was significant that the user group changed the AutoCAD in NAAUG to Autodesk. Carol Bartz gave the opening night keynote speech, and as she liked to do so often, emphasized the numbers associated with the company – two million users, 4,000 resellers, 2,000 application developers and 600 authorized training centers.

A new conflict was starting to emerge between the company and application developers that would only become more intense as time went on. The attitude among many developers was that Autodesk should focus on basic technology and they would create and market vertical applications as well as programs that filled gaps in the AutoCAD product. It is quite clear that Bartz did not buy into this separation of powers, especially in regards to product gaps in the short term and applications in the long term. The new mechanical packages based on the MES software was just the start.

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[30] Cohn, David, "What's Going On At Autodesk?, " *CADalyst*, November 1993, Pg. 14

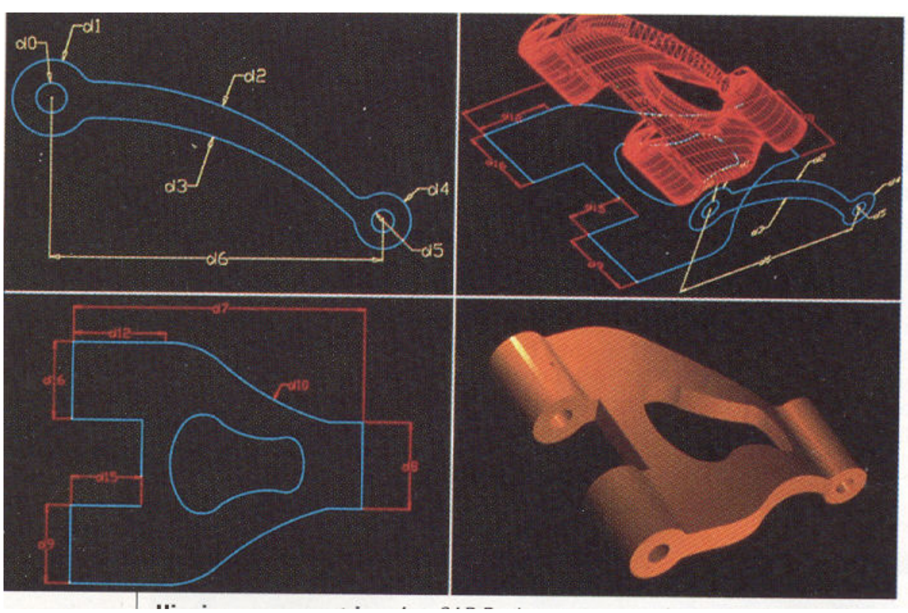
 

Two examples of this new philosophy were the AutoCAD Data Extension (ADE) which enabled users and developers to simultaneously access multiple AutoCAD files or multiple users to access the same drawing and an upcoming drawing management package tentatively named Technical Document Management (TDM). It was eventually release in August 1994 as WorkCenter. Other developments included the demise of AutoShade after Pixar withdrew the company's rights to resell RenderMan and the shifting of all Generic CADD development to the company's offices in California.

In early November 1993 Autodesk introduced a new Windows-based low-end drafting package called AutoCAD LT priced at $495. John Walker had initially recommended a low-cost version of AutoCAD as early as July 1984. At the time he called it AutoCAD Lite.[31] A major controversy swirled around this product in that Autodesk initially planned to include a version of AutoLisp but at the last moment decided not to do so. This severely limited the ability of user and third party developers to create applications on top LT. Obviously, the company was concerned that a version of LT that was too close to the capabilities of AutoCAD would reduce sales of the higher-priced package to the point that it would hurt the company's overall revenues.

**More emphasis on the mechanical market**

The major product announcement at AUTOFACT later that month was the introduction of AutoCAD Designer, a $1,500 ACIS-based front end to AutoCAD. Autodesk had acquired a small company in Oregon called Woodbourne that had previously developed a two-dimensional parametric front end to AutoCAD called Design Companion. The president of Woodbourne was Robert (Buzz) Kross who eventually would become a vice president at Autodesk and responsible for the development of all mechanical CAD software.




[31] Walker, John, "Expanding the Product Line," *The Autodesk File*, Pg. 219

Figure 8.4
AutoCAD Designer

While this early version of Designer had bi-directional associativity with AutoCAD and could handle under-constrained sketches and feature-based modeling, it could not handle assembly design. At the same time, Autodesk introduced AutoSURF 2.0, a NURBS surface modeler that was integrated with AutoCAD Release 12. The surfaces created with AutoSurf, however, could not be incorporated into Designer models.

Towards the end of 1993, the media started to get a good idea of what Autodesk was planning for AutoCAD Release 13, expected in the second half of 1994. It involved using HOOPS for the graphics interface, incorporating ACIS solids modeling in the basic product and changing the underlying architecture to a more object oriented methodology. I was not optimistic about the company's ability to pull this off:

> "When Release 13 does appear, probably in the second half of 1994, many users may decide to stick with Release 12 for a period of time. …Some users may feel that the new solids capability is not worth the effort of installing it and making it work in their design environment.
>
> "The odds are also good that Release 13 will have its share of bugs due to all the new technology incorporated in it. Also, many of the older PCs users currently have installed may not support Release 13. Autodesk will try to make the software as platform independent as possible, but there are a lot of odd configurations in daily use."[32]

As customers waited for Release 13, the company's revenue growth began to suffer. During the quarter ending January 31, 1994, revenues grew by just four percent to $102 million. To help jump start the company's business, Autodesk hired James D'Arezzo as vice president of marketing in mid-January. While D'Arezzo had no prior experience in the CAD industry he had held senior marketing positions at IBM where he had helped launch the PC and at Compaq Computer where he was a marketing vice president.

**Market changes impact dealer organization**

By early 1994 it was becoming clear that Autodesk was refocusing its energies on AutoCAD and related products. A new term the company was using was "adjacency." Executives such as Bartz and Herr often talked in the context that there were 10, 20 or even 50 users of graphic information for every AutoCAD user who created graphical data. One example frequently used by Herr was Chevron Oil Company which had about 100 copies of AutoCAD at the time. Herr described how the company was using GIS technology to manage it assets

[32] *Engineering Automation Report*, December 1993, Pg. 4

and that there was a need for a huge number of copies of a product such as LT to access the data Chevron created with AutoCAD.

They saw AutoCAD LT as providing a tool for these adjacent users and if they didn't provide it, someone else would. Autodesk felt that in the long run, LT would not adversely impact total revenues but would actually stimulate sales of the full AutoCAD package. It was a high risk move but one that eventually paid off for the company. Around this time, the company shipped the millionth copy of AutoCAD to Consolidated Edison in New York.

While the product line was being refocused on AutoCAD and related packages, the dealer channel was undergoing traumatic changes. For a number of years dealers had been selling AutoCAD for a miniscule profit, hoping to make their real profit on the sale of the computer hardware needed to run this software. Some dealers even assembled PCs from readily available components and made another $1,000 or so on each seat.

Two things happened in the early 1990s to upset this applecart. First, PCs sold by the major vendors achieved a much higher level of performance and there was less the dealer could add to these systems that would create incremental revenue. The second issue was that the prices for standard PCs dropped significantly and the profit on selling standard machines nearly evaporated. By 1994, most small dealers were struggling and an industry-wide consolidation started that continues to this day.

Autodesk tried to help the dealer channel by opening regional offices around the country in order to provide more local support. Initially, these offices did not handle direct sales but that would change with time. One major problem was that dealers were restricted to relatively small geographic areas. That meant that a large engineering firm with offices in ten cities might have to deal with ten different dealers. It would take some time before Autodesk solved this problem.

Autodesk also began insisting that AutoCAD and related products (but not LT) could no longer be sold by mail or telephone. Initially the company insisted that dealers have face-to-face contact with customers. In mid-1996 this was changed to an "Area of Primary Responsibility" which typically translated into the requirement that customers be within 250 miles of the dealer's office. Autodesk also began requiring dealers to provide weekly inventory status reports and other sales information.

**Release 13 – Major changes lead to significant problems**

At the A/E/C SYSTEMS '94 conference in June in Washington, D.C., Autodesk previewed Release 13. The software had a number of new entity types due to the new object-oriented data structure and the incorporation of ACIS, a new Application Programming Interface (API) for software developers and an improved Windows-oriented user interface. I was not terribly impressed, "Although there are some attractive new features in this release, for the most part, the changes simply add functions that other packages have had for some time." It looked like availability would slip into early 1995.[33]

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[33] *Engineering Automation Report*, July 1994, Pg. 9

 

Several months later at Autodesk University in Atlanta, the company demonstrated a more finished version of Release 13 and I was more impressed than I had been in June. Autodesk had added additional drawing productivity enhancements and the new user interface was very flexible. For the first time, the software would be available on CD-ROM. In fact customers would have to pay $245 extra to get the software on a set of 23 diskettes. Since less than 10 percent of AutoCAD sales were for one of the UNIX versions, Autodesk was requiring that the workstation vendors support porting the software to their platforms. A DOS and Windows 3.1 implementation of Release 13 began shipping in November 1994 with the Windows NT version several months later.

About the same time Autodesk reorganized into specific market groups with Dominic Gallello in charge of the mechanical group and Godfrey Sullivan in charge of the AEC group. The company also formed a new division called Autodesk Data Publishing whose first product was Autodesk Mechanical Library with drawing data for over 200,000 common parts from 17 manufacturers.

Release 13 got off to a rocky start and the situation did not improve much until Release 14 came out more than two years later. User complaints revolved mostly around performance issue, software reliability and product compatibility. Release 13 ran noticeably slower than Release 12, especially in Windows mode. In fact, AutoCAD was one of the last major applications where many users still preferred the DOS version.

Autodesk probably contributed to this dissatisfaction by not recommending more aggressively that customers upgrade their PC hardware in order to adequately support Release 13. A new version utilizing graphics technology the company referred to as WHIP, came out in 1995 and improved the situation somewhat, especially for Windows NT.

Within four months the company shipped two maintenance updates. The current version as of March 1995 was Release 13c2 which proved to be fairly stable. In early 1996, the company began shipping Release 13c4 which was Windows 95 compliant and included ARX (AutoCAD Runtime Extension), a C++ application programming environment for software professionals. Release 13 did get Autodesk's revenue growth back on track, at least for a few quarters but then it basically stalled again as customers became increasingly concerned with performance, reliability and compatibility issues. Many customers were still using Release 10 and 11 in late 1996.

In April 1995, Autodesk released AutoCAD LT Release 2 which was a substantial improvement over the initial LT product. One problem was that it was still compatible with AutoCAD Release 12, not Release 13. If a Release 13 users wanted to transfer data to LT it had to be saved in the Release 12 file format and then transferred. It would June 1996 before the company released AutoCAD LT Release 3 for Windows 95 that was file compatible with AutoCAD Release 13. Possibly the best comment on Release 13 was John Lynch's: "One of the issues we came up against in Release 13 was that we tried too hard to be all things to all people."[34]

[34] *Cadence,* November 1996, Pg. A29

 

**Interoperability**

Beginning in the spring of 1995 the issue of data interoperability took on new importance as Autodesk pushed the concept of object-oriented data structures. Initially, the intent was to get AutoCAD applications to share more than just the graphic representation of objects such as doors, windows, valves, etc. The first step in this direction was the establishment of the Industry Alliance for Interoperability (IAI) which was established to publish definitions for these objects called Industry Foundation Classes (IFC).

The first attempt was to create a class library for commercial buildings. For a long time IAI efforts were almost entirely AEC-centric. A significant development occurred when Bentley Systems joined IAI later that year.

Autodesk also began offering an OEM version of AutoCAD with one significant caveat – they would not license this software to any company that offered or planned to offer a product that competed with any Autodesk products. As a consequence, there were few takers.

**Autodesk launches Mechanical Desktop**

In the fall of 1995 Autodesk announced a new mechanical design and drafting product called Mechanical Desktop. It combined AutoCAD Designer 2.0, AutoSurf 3.0, AutoCAD Release 13, IGES and software that tied it all together in a single integrated solution. Previously, users had to translate data to move between these applications. The intent for Mechanical Desktop was to move away from just mechanical drafting to true product design with tools incorporated to facilitate assembly modeling.

While not competitive with products such as Pro/ENGINEER or Unigraphics, it was a distinct step forward. Autodesk also had to compete with new products such as SolidWorks and Intergraph's Solid Edge, both of which were introduced around the same time. The major shortcoming was that users had to work interactively in a wireframe mode while competitive products allowed them to work with hidden lines removed or with shaded images. The suggested list price was $6,250.[35]

Shipment of a production release of Mechanical Desktop was delayed until early 1996. At that time, Dominic Gallello clarified the company's mechanical market position as still being drafting-centric rather than competing directly with heavyweight competitors such as PTC or the new mid-range vendors. Basically, the company was planning on playing to its strengths, at least for the time being.

Mechanical Desktop Version 1.1 was released in September 1996 with the major enhancement being the ability to work with shaded or hidden line models. The company also release Web version of PartSpec and WorkCenter.

A substantially new version of Mechanical Desktop had to wait for AutoCAD Release 14 described below. A few months after Release 14 began shipping the company began delivering Mechanical Desktop Release 2.0 that incorporated Spatial Technology's ACIS Version 3.0. Compared to the prior version Mechanical Desktop Release 2.0 had improved geometry definition capabilities, improved performance, better assembly modeling and an improved user interface. The company also launched an enhancement to AutoCAD Release 14 that facilitated mechanical drafting. It was simply called AutoCAD Mechanical.

[35] Mechanical Desktop was known as Project Texas during development

 

In May 1998, Autodesk acquired Amberg, Germany-based Genius CAD-Software GmbH for $68 million. This company was a leading vendor of mechanical design automation software in Europe. The company's primary product was Genius Desktop, a plug-in for Autodesk Mechanical Desktop that provided a more vertically focused set of features for electromechanical and industrial machinery design. The downside to the acquisition was that third party software partners began to see Autodesk as one of their primary competitors.

**Multimedia business becomes separate division**

Visualization and animation had been an important element of Autodesk's business model for a number of years. In April 1996 the company gave this activity more focus by changing the Multimedia Market Group to a separate entity called Kinetix, relocated from San Rafael to San Francisco. The new unit's general manager was Larry Crume.

Kinetix was responsible for products such as 3D Studio and 3D Studio Max as well as Internet initiatives including a new AutoCAD format called DWF (Drawing Web Format). A year later, a new package, Autodesk Walkthrough, was introduced that facilitated animated visualizations of proposed facilities such as office buildings and process plants.

**Autodesk acquires Softdesk**

By late 1996 Eric Herr had become president and COO of Autodesk and was taking on so much responsibility, that I predicted in January 1997 the Carol Bartz might be leaving and going into politics. One of the reasons I made this prediction was that when Autodesk announced on December 10, 1996 that it was acquiring Softdesk for $72 million (later raised to $90 million when PTC came in with a competitive offer) it was Herr who made the announcement, not Bartz. The final acquisition price was about twice Softdesk's annual revenues.

Softdesk was founded in 1985 by David Arnold and David Paine as DCA Engineering, a civil engineering and surveying firm in Henniker, New Hampshire. It was an early user of AutoCAD and in 1987 decided to begin developing civil engineering and surveying software packages that ran on top of AutoCAD. The company kept the prices for its packages reasonably low and used many of the Autodesk dealers to sell these programs. In 1991 the company's name was changed to Softdesk and it quickly became the largest third party developer of AutoCAD applications. In 1993, Softdesk acquired Archsoft Group (ASG) which was located in Sausalito and was the second largest vendor of AutoCAD applications. ASG was also the original developer of the AutoCAD AEC application described earlier. ASG's founder, Jesse Devitte, remained with Softdesk after that deal occurred as well as after the Autodesk acquisition.

The company's revenues hit $14.5 million in 1993 and in early 1994 Softdesk went public. Using its stock and some cash, the company began acquiring a number of smaller software firms in order to fill out its suite of AEC applications. These companies included:

- Image Systems Technology (raster image software)
- IntelliCADD (software for the utility industry and the developer of the technology used in AutoCAD Data Extension)

- Advantage Engineering (process plant design software)
- Foresight Resources (low-cost architectural applications).

The acquisition of Softdesk was a significant move by Autodesk in that it now put the company in direct competition with many of its third party developers. The plan was to make Softdesk the base for the company's AEC Market Group with Arnold in charge, reporting to Herr. This only lasted a short while and by fall Arnold had moved to the position of chief technology officer for the company and Devitte was the general manager of the AEC group. Subsequent to AutoCAD Release 14, a new release of the Softdesk software was made that was referred to as Softdesk 8.

There was a significant antitrust issue that nearly derailed the acquisition. After acquiring IntelliCADD, Softdesk put its programmers to work creating a low-cost clone of AutoCAD. The Federal Trade Commission felt that Autodesk's acquisition of Softdesk would eliminate potential competition and it held up the deal until Softdesk agreed to spin off that operation as Boomerang Technology which was then acquired by Visio. The AutoCAD knockoff was subsequently given the temporary name of Phoenix and was eventually released in early 1998 as Visio IntelliCAD using a reverse-engineered AutoCAD DWG file format as its underlying data structure.

**AutoCAD Release 14 – finally**

Nearly two and a half years after ill-fated Release 13, Autodesk launched AutoCAD Release 14, a significant improvement over the prior version. In March 1997, *A-E-C Automation* personnel tested a beta version of the software and were impressed with its reliability, performance, improved user interface and tighter integration with other Autodesk products. Other than the ability to work with hybrid raster and vector drawings there were few new functional enhancements this time around. [36]

The beta test program involved over 16,000 users, a first for the company. The price remained at $3,750 with subsequent upgrades available for $295 per year through the company's new VIP Subscription Service. This was a Windows 95 and NT only release. There were no plans to produce DOS or UNIX versions of Release 14 or support earlier versions of Windows and the software was available only on CD-ROM. No more diskettes.

Release 14 was shown publicly at A/E/C SYSTEMS '97 in Philadelphia that June. The keynote address contained one of the best lines ever heard at a CAD industry conference. Sitting between Intergraph's Jim Meadlock and Bentley Systems' Keith Bentley who were in the middle of a nasty legal dispute, Carol Bartz started her talk with, "I feel like a rose between two thorns."

Autodesk began shipping Release 14 on May 9, 1997 and not a moment too soon. Revenue for the quarter ending April 30th were down 13 percent from the prior year to $119 million and the company lost $52.7 million (this was after a $58.1 million charge related to the acquisition of Softdesk). With Release 14 receiving a good reception from users and prospects, sales soared to $154 million the following quarter and earnings were once again positive at $17.8 million. With just the U. S. version available, Autodesk still shipped 60,000 new seats and 65,000 upgrades during the quarter. Release 14 truly marked an inflection point in the history of Autodesk although AutoCAD now amounted

[36] *A-E-C Automation Newsletter*, March 1997, Pg. 1

to just 75 percent of the company's overall revenues, down from the 90 percent it represented a few years earlier.

A few months later the company began shipping Mechanical Desktop 2.0 which incorporated Release 14 and ACIS 3.0. It included a new model browser, shelling, improved fillets and blends and an improved menu structure. The company's MAI (Mechanical Applications Initiative) Partnership was attracting third party software developers who marketed a growing number of Mechanical Desktop applications including finite element analysis (FEA), kinematic simulation, mold design, tolerance analysis and NC.

Visualization was starting to become more of a mainstream activity. While 3D Studio MAX was an excellent package, it took far too much effort to learn for casual users. Autodesk responded by introducing 3D Studio VIZ, an easier to use visualization package aimed at broadening the market. Although it appeared that Autodesk was starting to get its act together, there was a potential cloud on the horizon. The threat goes back to John Walker's "Nightmare Scenario" where he forecast that a low-end competitor (potentially Microsoft) would come out with a substantially lower cost version of AutoCAD. That threat appeared to be Visio's Phoenix project mentioned earlier.

For $500 users could have a package that emulated 90 percent of AutoCAD's functionality and was file compatible with earlier versions of AutoCAD back to Release 10. *Forbes* thought this was a real threat: "If the easy-to-use Phoenix fulfills its promise of AutoCAD compatibility, it could displace AutoCAD even among hard-core technical users."[37] That never did happen, as described in Chapter 21.

In October 1997, the company held its first Autodesk Design World which combined the Partner Summit (previously CAD Camp) and Autodesk University at the Los Angeles Convention Center with 5,300 people attending. The meeting was kicked off with a video introduction by Microsoft's Bill Gates followed by an upbeat presentation by Carol Bartz that emphasized the three building blocks for the future at Autodesk – intelligent objects, the Web and three dimensional modeling. At this point, the company products and markets and the unit managers were:

- Geographic Information Management Systems – Dr. Joesph Astroth
- Mechanical – Dominic Gallello
- AEC –Jesse Devitte
- Personal Solutions (AutoCAD LT and Autosketch) – Godfrey Sullivan
- Kinetix – Jim Guerard
- AutoCAD – Robert Carr

In mid-1998, Autodesk introduced a new AutoCAD application development tool called Visual LISP. A significant differences with the earlier AutoLISP was that the new version resulted in compiled code rather than interpreted applications. Hence, they ran as much as two to five times faster. Also, Visual LISP could access Release 14's object-oriented files through the use of Autodesk's ObjectARX programming environment.

**OpenDWG Alliance**

One of the byproducts of AutoCAD success was that there was a growing number of companies that wanted to directly read and write DWG files. Autodesk's response was

[37] Young, Jeffrey, "The Case of the Unlucky 13," *Forbes*, September 22, 1997, Pg. 236

 

to offer an OEM version of Release 14 except, as mentioned earlier, not to competitors. A number of companies used DWG information that had been reversed engineered by MarComp, a two-person software firm. Sensing something better organized was needed, Visio Corporation, which had earlier acquired MarComp, convinced about 15 other software companies to contribute $25,000 each towards establishing the OpenDWG Alliance (ODA) in February 1998. Significantly missing from this first group of members was Bentley Systems. Autodesk had been asked to join but refused for obvious reasons.

One of the first actions was to run a full-page add in *The Wall Street Journal* attacking Autodesk for keeping the DWG format proprietary. This was somewhat hypocritical in that most of the Alliance members kept their own file formats proprietary. Visio contributed the MarComp technology to ODA and the original developers of that software continued to work on it. ODA periodically released new software that enabled its members to read and write the latest AutoCAD DWG files. Evan Yares became executive director of ODA in September 1998 and in October 2003, after Bentley joined, the name was changed to the Open Design Alliance.

Autodesk's position over the years was that no one else could provide DWG compatibility to the extent that it could since Autodesk controlled the content of the format and did not have to reverse engineer data files.

**Autodesk's product line expands**

In early 1998, Mark Sawyer, who had previously been with Auto-trol Technology and Spatial Technology, became general manager of the AEC Market group and was subsequently promoted to vice president. He reported to Carl Bass who was the company's chief technology officer (Dave Arnold had left the company by then). Bass was in charge of a new AECAD Group which combined AutoCAD and the AEC Market group.

That May, the company introduced AutoCAD Architectural Desktop, an integrated solution for building design along the lines of the previously described Mechanical Desktop product. It added a number of object-oriented architectural features to AutoCAD Release 14 and provided an incremental step for users interested in moving to three-dimension building modeling. The company tended to downplay this later aspect of the product. According to Ian Howell, an AEC marketing manager: "We made a decision early in the design of the product that we would not mandate our users into 3D data input."[38] Architectural Desktop, which began shipping in October, had a list price of $4,795.

The architectural software was followed a few months later by a new suite of civil engineering and surveying software. The base product was called AutoCAD Land Development Desktop which consisted of AutoCAD Release 14, a GIS module called AutoCAD Map 3.0, new menus, an enhanced symbol library and some application specific functions. This had a list price of $4,995. The company also launched two add-on applications, Autodesk Survey and Autodesk Civil Design. Survey was priced at $995 while Civil Design was an additional $2,995. These prices were less than competitive packages such as Intergraph's INROADS, but also were functionally less extensive. Except for process plant design, Autodesk was now in direct competition with most of its third-party AEC software developers.

[38] *A-E-C Automation Newsletter*, June 1998, Pg. 6

 

The next major move was the acquisition of Discreet Logic, based in Montreal, Canada, that was announced on August 20, 1998. Discreet was a developer of high-end visualization and animation software used primarily in the entertainment industry for films such as *Armageddon*, *Titanic* and *Independence Day*. It took until March 1999 to complete this deal. The acquisition involved the issuance of about ten million shares of Autodesk stock worth approximately $410 million at the time. The plan was to combine Discreet and Autodesk's Kinetix business unit into a single activity using the Discreet name. At the time, Discreet had annual revenues of about $150 million. This did not turn out to be a great move for Autodesk in the long run and seven years later revenues for this business are about the same as they were in 1999. One result was that 3D Studio Max eventually became 3ds max (later 3ds Max) as the computer industry became enchanted with lower case business and product names. 3D Studio VIZ simply became VIZ

By the end of 1998, Autodesk had sold two million copies of AutoCAD and more than 800,000 of AutoCAD LT. The company also launched Actrix Technical, a two-dimensional software package clearly aimed at competing with Visio.

**Autodesk changes AutoCAD nomenclature**

In early 1999 Autodesk launched a new version of AutoCAD called AutoCAD 2000 rather than Release 15. There were more than 400 enhancements in this release, most of which were rather minor but a few were particularly significant. Overall, this version represented a maturing of the object-oriented ARX technology originally introduced with ill-fated Release 13.

With AutoCAD 2000, Autodesk completed the transformation of AutoCAD to a fully object-oriented architecture. This was key to supporting applications such as Architectural Desktop and Land Development Desktop. Equally important was the transition to a fully-compliant Windows implementation of the software. Users familiar with Microsoft operating systems and applications could now feel equally comfortable with AutoCAD and were ensured that data could be moved between AutoCAD and other Windows-compliant applications.

With Autodesk no longer supporting UNIX, DOS or MAC/OS, the company's programmers were able to take advantage of all the capabilities built into the Windows operating systems including file management, menu management, input and output device control, network communications and many other "housekeeping tasks." Leaving these tasks up to the operating system made Autodesk's software more compatible with other applications. In addition, it freed up programming resources that could be assigned to other projects. During development of Release 9 and 10, the company's programmers probably spent 70 percent or more of their time on these housekeeping tasks. By the time AutoCAD 2000 was released, they were probably spending less than 20 percent.

The most significant functional enhancement was the ability to open several drawings at the same time and display them in individual windows or overlapped like tabbed folders.

AutoCAD 2000 was somewhat slower to take off than initially expected. Release 14 had been a significant enhancement over Release 13 and many users (about 45 percent were using Release 14) were satisfied and saw no immediate need to upgrade. Also, it took some time for Autodesk and third party applications that were compatible with

 

AutoCAD 2000 to become available. One result was that revenues for the quarter ending April 30, 1999 dropped 13 percent to $195 million.

In mid-2000, the software was updated with a number of Web-centric capabilities and renamed AutoCAD 2000i. This nomenclature was also used for other AutoCAD and LT-based products. At the same time, the company launched a Web-centric method for customers to access information from Autodesk called simply Autodesk Point A.

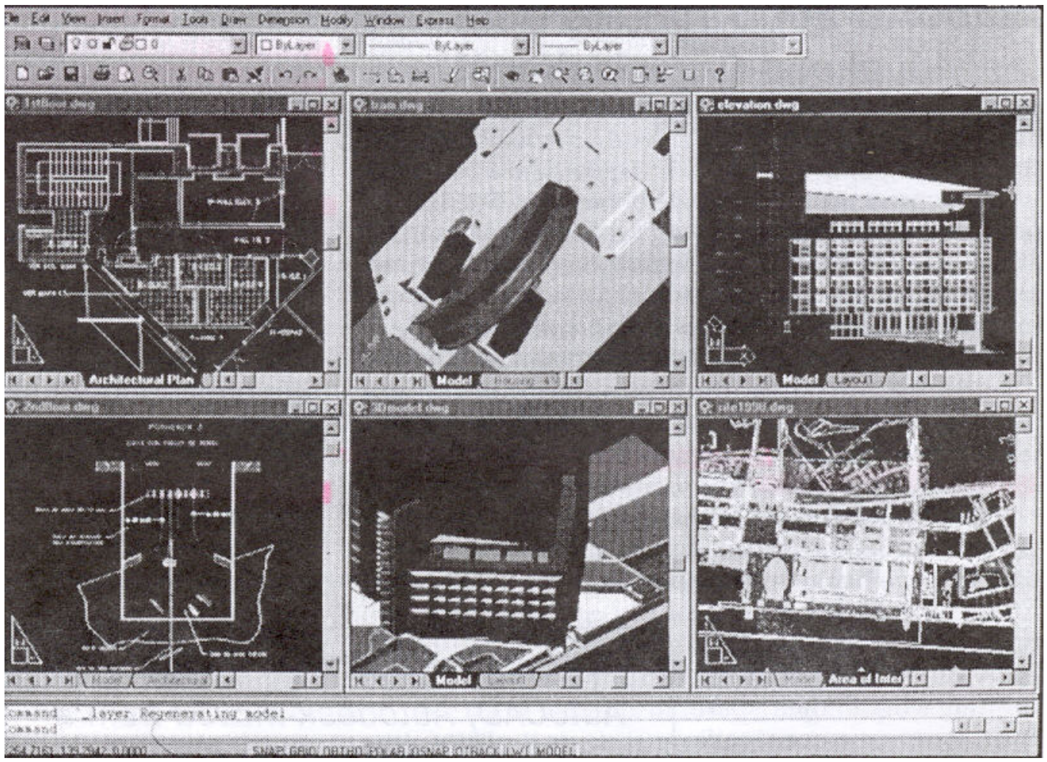


Figure 8.5
AutoCAD 2000 Multiple Design Environment

**Let's rearrange the deck chairs one more time**

It seemed as if Autodesk was constantly looking for the "right" organizational structure that would propel it into the ranks of leading software companies. With revenues stagnant in mid-1999, it was time to rearrange the deck chairs one more time. First, Eric Herr announced that he was retiring and Carol Bartz took back the position of president which she had relinquished several years earlier. The company was then restructured into four business units each headed by an executive vice-president.

- **Design Solution Division** (Dominic Gallello) – responsible for industry specific applications in mechanical and AEC areas as well base products such as AutoCAD and AutoCAD LT.
- **Discreet Division** (Godfrey Sullivan) – responsible for digital media tools as well as previous Kinetix products such as 3D Studio Max. In early

 

2005, this group was renamed the Autodesk Media and Entertainment division.

- **GIS Solutions Division** (Joe Astroth) – responsible for mapping and utility information management applications. In April, Autodesk had acquired Vision* Solutions Group, a software firm that specialized in mapping applications for utilities. The company paid $26 million for this division of MCI Systemhouse. This division also was given the responsibility for Land Development Desktop and other civil and surveying applications in either 1999 or 2000. Later, it was renamed Location Services Division.
- **Autodesk Ventures** (Carl Bass) – responsible for new business opportunities such as Web-based services. Bass retained his position as chief technology officer.

The reorganization was probably caused in part by the fact that revenues were continuing to deteriorate. Revenue for the quarter ending July 31, 1999 was down 11 percent to $203 million. AutoCAD 2000 was a solid piece of software but customers were upgrading slowing. By the end of the quarter, only eight percent of the user base had upgraded. Since the company's cost structure was based on the expectation of higher revenues, Bartz announced a 10 percent layoff or about 350 positions. Analysts were turning negative on the company. The Motley Fool web site was perhaps the most cynical:

> "The company cranked up the same excuse broken record it has used to explain away year-over-year earnings declines in the prior two quarters, blaming the shortfall on product transition factors and slack demand for its core PC design software products. …… Fearing the product transition explanation may be wearing a little thin on investors who have watched 42% of the company's market value evaporate so far this year, Bartz offered up a new spin on things. It seems that customers are more interested in Web-based applications than the plain-vanilla offerings Autodesk has been serving up. In response, the company will be plowing some of the cost savings it reaps from the job cuts into developing Internet-enabled products. However, it will take some time for the new Web efforts to ramp up, suggesting Autodesk's shareholders will get more doses of the broken-record blues in Q3 and Q4."[39]

**Buzzsaw.com joins project management web hosting parade**

By 1999 one of the hottest areas of activity in the AEC market was the management of design and construction projects using Web hosting techniques. The concept involved storing design documents on a Web server and providing access to these documents as well as a variety of project management services to all the individuals involved in the project. Over a period of several years more than $1 billion in venture funding was provided to nearly 170 companies including Blueline/Online, BricsNet, Bidcom, Cubus, Buildpoint.[40]

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[39] Motley Fool Web Site
[40] Cohen, Peter S., "Deconstructing Buzzsaw.com," *The Standard*, May 15, 2000

 

Autodesk was not to be left out of this parade but on the other hand, did not want to have the startup costs for entering this business impact the company's earnings. The way around this was to set up a separate company in December 1999 called Buzzsaw with $15 million in initial funding from Autodesk and another $15 million from Crosspoint Venture Partners. The company subsequently raised a total of $90 million of venture funding. Carl Bass and Anne Bonaparte moved over from Autodesk to run Buzzsaw.

The initial product was called ProjectPoint. The plan was to provide the management of a limited amount of data for free (initially 100 MB) and to charge for larger projects. Like many other dot com startups, Buzzsaw also talked about generating revenue from advertising and other services such as transaction fees on building components ordered through ProjectPoint. By mid-2000, Buzzsaw had 240 employees, 10,500 projects on-line and 50,000 registered users. One early customer was Bank of America which was using Buzzsaw to help manage its commercial construction lending business.[41] Buzzsaw was chewing up cash at a $10 million per quarter rate.

In April 2000 the company invested in a second information management company called RedSpark.com that targeted manufacturing industries. Dominic Gallello moved over from Autodesk to head up this startup. By later that year, Autodesk owned a majority of both Buzzsaw and RedSpark and as a consequence was required to consolidate their losses with its financial results. In March 2001, RedSpark announced RADIPteam, a solution for communication and collaboration between project managers, engineers, and material suppliers, and ProductEdge, an eBusiness platform for standard component manufacturers.[42]

In a somewhat hard to follow move, Autodesk established another on-line project management service as part of its Inventor initiative (see below) called Streamline. Launched in February 2001, it was a hosted online service for sharing digital design data across the extended manufacturing enterprise, including sales, marketing, purchasing, documentation, the shop floor, and suppliers.

It is interesting to note that Bartz assigned two of her top executives to run these startups, neither of which ever made it as independent companies. When Buzzsaw was brought back inside the corporate fold in mid-2003, Bass returned to Autodesk as the company's chief operating officer while Bonaparte became president and CEO at MailFrontier, a vendor of email security and anti-spam software.

RedSpark, on the other hand, was simply disbanded in October 2001 and the entire staff of 42 employees including Gallello were laid off. Autodesk cited "a weak manufacturing economy and a difficult private capital market," and was quick to note that RedSpark was not part of Autodesk, but rather a company that Autodesk had nurtured and invested in. There was apparently overlap with the previously mentioned Streamline product which was probably why Autodesk did not simply acquire the portion of RedSpark it did not already owned and bring the company in-house as it did with Buzzsaw.

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[41] Autodesk Press Release, April 10, 2000

[42] *Engineering Automation Report*, April 2001, Pg.16

 

Streamline is an Autodesk hosted system based on software from eRoom Technology and RealityWave. It enables the creators of data to post design information that can then be accessed by others within the company or by outside suppliers such as machine shops. Basically, it does for manufacturing companies what Buzzsaw does for AEC-related firms.

**Autodesk launches Inventor – a new mechanical design package**

Mechanical Desktop as described above targeted mechanical designers who considered that compatibility with AutoCAD and its DWG file format to be more important than having the most effective design tool. Autodesk recognized early on that this was an interim solution and that eventually it would have to provide a more up-to-date feature-based parametric modeler if it were to become a major player in the mechanical CAD arena.

Work on a new, built from the ground up, software package, code-named Rubicon, began in early 1996. During the next several years, Autodesk spent over $25 million and built up a team of more than 90 people working on this project in Tualatin, Oregon under the supervision of Buzz Kross. Prior to its release in late 1999, the new software was named Autodesk Inventor. It used Spatial Technology's latest geometric kernel, ACIS 5.2.

There were several key aspects to this package. Autodesk put substantial effort into making the software easy to use with minimal initial training. One characteristic of this was Inventor avoided most of the difficult parent/child restrictions that users of other systems such as Pro/ENGINEER had to work with. The company also claimed that Inventor would handle large assemblies without undue problems. The latter was accomplished through the use of a new data architecture called a segmented database.[43]

Introduction of Inventor did not mean that Autodesk was abandoning AutoCAD-based mechanical design. New releases of both AutoCAD Mechanical and Mechanical Desktop continued to be worked on. The company added what it called "Power Packs" to these products that incorporated technology obtained when it had earlier acquired Genius. Basically, Autodesk wanted to claim that it provided the best technology for users who wanted to move from two-dimensional to three-dimensional design while at the same time continue to generate substantial revenue from customers who wanted to continue working in a drawing-centric mode.

Within a few months the company began shipping Inventor Release 2 with improved assembly modeling capabilities, sheet metal modeling and improved drafting. It still did not have the surface geometry capabilities of the Mechanical Desktop package. By late 2001 the company was shipping Inventor Release 5 although it still did not have significant surface geometry capabilities. As of the end of 2001, Autodesk had shipped more than 50,000 copies of inventor.

**Autodesk and the 21st Century**

In the early years of the new century, Autodesk focused on consolidating its product line and attempted to get its revenue growth back on track. It took a

[43] *Engineering Automation Report*, September 1999, Pg. 9

 

few years, but by 2005 the company seemed to be on a roll. After nearly doubling between fiscal 1995 and 1999 to $894 million, the company's revenues were erratic to say the least over the next five years, sinking to $825 million in fiscal 2003 and never getting much above $950 million. Then in the last quarter of fiscal 2004, it was as if someone lit the corporate afterburner as revenues for the quarter increased 51 percent to $295 million. Revenues soared to over $1.2 billion in fiscal 2005 and the company earned more than $220 million. Fiscal 2006 was even better with revenues of $1.5 billion and earnings of over $300 million. The company's stock jumped from a split adjusted $10 in mid 2003 to nearly $50 per share in late 2005. In May 2006, Carol Bartz became executive chairman of the company and Carl Bass became CEO.

Some of the highlights during this period not mentioned earlier or simply involving normal product enhancements included:

- In late 2001, Autodesk announced that it planned to develop its own geometric modeling software called ShapeManager based on Spatial's ACIS 7.0. This move was partially a result of the fact that Spatial was now a Dassault Systèmes subsidiary and partially the desire by Autodesk to control its own technology. Under its earlier license agreement with Spatial, Autodesk had rights to a permanent license of the ACIS kernel.
- Spatial sued Autodesk claiming that the latter company had breached its contract by improperly providing access to the ACIS source code to third parties including D-Cubed, a developer of constraint management software. In October 2003, a jury ruled in favor of Autodesk.
- Autodesk acquired Revit, a vendor of architectural modeling software, for $133 million in January 2002. Revit was started by several ex-PTC software developers and was becoming a significant player in the architectural modeling market. Under Autodesk, Revit sales initially grew rather slowly. In late 2003, the company combined Revit with AutoCAD 2004 into a product called Revit Series in an attempt to stimulate sales. Revit currently represents a distinct platform within the company's Building Solutions Division, much the way Inventor is a platform within the Mechanical Solutions Division. A major differentiator, however, is that while Inventor competes against the likes of SolidWorks, Solid Edge, CATIA, Pro/ENGINEER, and a host of others, Revit has significantly less competition. Autodesk coined the acronym BIM (Building Information Modeling) to identify the way Revit enables architects, designers, and engineers to capture decisions during the design process and incorporate them into the overall database that represents the 3D virtual prototype of the building. This technology is now being mandated by the General Services Administration (GSA) and a number of major corporate developers.[44] By 2007, Autodesk was selling 75,000 copies of Revit annually.

[44] Personal correspondence from David Cohn

- Later in 2002, Autodesk acquired CAiCE Software Corporation, a Tampa, Florida based developer of surveying and civil engineering software, for $10 million. This acquisition provided Autodesk with highway design software capable of competing against similar applications offered by Bentley Systems.
- Autodesk bundled Inventor, AutoCAD Mechanical and Mechanical Desktop into a single product bundle called Inventor Series (now known as Inventor Suite) in early 2002 and priced this software suite at $5,195, just slightly more than the price of Inventor itself. The street price tended to be closer to $4,000.
- Autodesk has continued to update AutoCAD with additional three-dimensional capabilities, user interface improvements and better data interaction with databases and spreadsheets. By 2007, the company was selling nearly 250,000 copies of AutoCAD annually included copies included with various product suites. This was in addition to another 325,000 copies of AutoCAD LT annually.
- Gradually, the company began to increase its direct sales as a complement to its dealer network, especially in the mechanical CAD market.
- Autodesk continued to move its customers to the company's VIP subscription service. In some cases, specialized services were only available to customers who were VIP subscribers.
- Increasingly, the company focused on information management and collaboration software tools. The company's products, especially in the mechanical arena began to take on more and more of the characteristics of the company's larger competitors such as PTC, Dassault Systemes and UGS.
- The company attempted to regain a more profitable business model including a layoff of over 550 people in early 2004. Autodesk also drove upgrade revenue by more aggressively capping support for earlier releases of its software products. At some point, a user could no longer upgrade an earlier release but had to purchase a new license in order to obtain the latest version.
- Autodesk added Computer-Aided Industrial Design(CAID) to its product portfolio in 2005 when it acquired Alias, a Canadian software firm for $182 million in cash. Alias, founded in 1983, was acquired by SGI in 1995 and merged with Wavefront to form Alias|Wavefront.[45] It was sold to a group of private investors in June 2004 for about $57 million who quadrupled their money in a little over a year when they sold it to Autodesk.
- The company is also moving more aggressively into the process plant design market. In 2007, it released a drafting application particularly targeted at producing P&ID drawings and it plans to offer a piping design package in the near future.

[45] *Engineering Automation Report*, August 2003, Pg. 3

 

**Why did Autodesk succeed when so many others failed?**

The simple answer to this question is that in 1982 the existing CAD companies were wedded to traditional product concepts and business practices at a time when the computer industry was in the very early stages of revolutionary change. Autodesk recognized the impact the personal computer would have on this industry while the firms who dominated the industry in 1982 ignored this trend for far too long.

When Autodesk was started, the CAD industry was dominated by five major turnkey vendors: Auto-trol Technology (no longer in the CAD business), Applicon (acquired by UGS), Computervision (acquired by PTC), Calma (acquired by Prime Computer then merged with Computervision prior to the latter company's acquisition by PTC), and Intergraph, all of which had sales exceeding $50 million per year. All five had a number of characteristics in common.

- They were hardware manufacturing companies as well as software vendors.
- They designed and built specialized graphics workstations that only ran their software.
- The typical system sold for $80,000 to $125,000 per seat.
- They provided all training and customer requests for customization.
- The systems were sold by a direct sales force.
- In 1982, they were all in the process of migrating from 16-bit computer systems to 32-bit systems.
- The new computer of choice was the Digital VAX 11/780.
- All applications were developed and sold by the system vendor except for the occasional analysis package.

There were numerous other vendors chasing after this business. Some, such as Gerber and IDI, also sold similar high-priced turnkey systems. There were also a number of so-called low cost system vendors. In 1982 low cost was defined as under $80,000. Most of this later group of vendors (Arrigoni, Bruning, Summagraphics, Sigma, Calcomp, Nicolet-CAD, et al) also designed and manufactured specialized graphics hardware to support their software. In general, none of these companies took Autodesk seriously until it was too late.

Autodesk was successful for a number of business and technical reasons.

- The company was started on a cooperative basis with most of the founders having other jobs from which they earned enough to live on.
- They were excellent programmers.
- Walker managed the company's money very tightly—one could almost say he was as paranoid about expenses as he was about taxes.
- The company used standard PC hardware to the maximum extent possible.
- The software was priced low enough that most early users did not require a very high level of management approval for the purchase. Since hardware was purchased separately, a system could be split into two small procurements. It was also cheap enough for educational organizations and commercial training schools to buy.
- They quickly moved to support numerous foreign languages.

 

- Autodesk built a killer distribution channel. By 1985, more than 1,000 ComputerLand and Entre stores were handling AutoCAD in the U.S. and more than 500 dealers were selling this software in 40 foreign countries. Autodesk also sold a significant number of copies on an OEM basis through several PC manufacturers.
- Much of the sales expense such as training sales personnel and application engineers was absorbed by the dealer channel.
- Dealers provided much of the training and technical support. Mike Ford, in particular, felt that this saved Autodesk considerable expense during the early years.
- Customers paid for software upgrades when they came out.
- While dealers made some money selling AutoCAD, they made the bulk of their profit selling the PC hardware they configured for their customers. The most significant source of profit for many dealers was the money they made on training and support.
- The company welcomed third-party software developers and did not view them as competitors as did the large turnkey vendors. By June 1985 there were more than 100 such packages. Within a few years there would be thousands.
- One of the big factors that differentiated AutoCAD from most of its PC-based competitors was that, except for a short period of time, it had no copy protection on North American licenses. Other packages such as VersaCAD and CADplan had hardware locks. Since AutoCAD was easy to copy, many people did so and the number of pirated copies soared. This dramatically increased the number of trained users. Eventually, Autodesk implemented an anti-piracy campaign and even paid dealers a bounty to turn in organizations using stolen software. Autodesk has used hardware locks only on international copies of its software. The company has predominately relied on license agreements to control the number of illegal users.

The bottom line is that Autodesk was in the right place at the right time and it did not blow the opportunity as so many other companies in a similar position have done over the years. AutoCAD was not the only PC CAD package introduced in the early 1980s, but it definitely was the most successful.

**Financial results**

Some years have been restated due to mergers and acquisitions. Also, the company currently reports earnings on a pro forma basis that makes it difficult to compare recent earnings with earlier periods. Typically, special charges due to acquisitions are excluded from the earnings numbers.

| **Year ending January 31** | **Revenues in millions** | **Profits in millions** |
|---|---|---|
| 1983 | $0.015 | ($0.009) |
| 1984 | $1.2 | $0.1 |
| 1985 | $9.9 | $1.6 |
| 1986 | $29.5 | $6.5 |
| 1987 | $52.4 | $11.6 |
| 1988 | $79.3 | $20.5 |
| 1989 | $117.6 | $32.7 |
| 1990 | $178.6 | $46.4 |
| 1991 | $237.9 | $56.8 |
| 1992 | $284.9 | $57.8 |
| 1993 | $353.2 | $43.9 |
| 1994 | $405.6 | $62.2 |
| 1995 | $454.6 | $56.6 |
| 1996 | $534.2 | $87.8 |
| 1997 | $496.7 | $41.6 |
| 1998 | $786.1 | $56.2 |
| 1999 | $893.8 | $97.1 |
| 2000 | $848.1 | $9.8 |
| 2001 | $936.3 | $93.2 |
| 2002 | $947.0 | $119.0 |
| 2003 | $824.9 | $31.9 |
| 2004 | $951.6 | $120.3 |
| 2005 | $1,234 | $221.5 |
| 2006 | $1,523 | $316.4 |
| 2007 | $1,840 | $349.7 |

 

# Chapter 9

# Auto-trol Technology

*Author's note: I joined Auto-trol Technology in January 1980, initially as director of product planning. In subsequent years I was director of product marketing, director of AEC application development and director of marketing support where my primary responsibility was competitive analysis. In late 1985 I started a government sales organization, an assignment that lasted until late 1990. During my last year at Auto-trol, I was responsible for both the AEC and Technical Publishing business units. As a consequence, much of this chapter is based upon my own experiences at Auto-trol.*

**Auto-trol's evolution as a company**

Auto-trol Corporation was founded in 1962 by Bill Barnes and his wife, Tammy, whom I had worked with at the Colorado Department of Highways in 1960. Bill was an extremely creative engineer who was always coming up with novel ideas for new products and markets, some of which were practical and some less so. The company's name came from "Automatic Control." Its initial focus was in building industrial control systems, including control equipment for bakeries.

Fairly soon, however, Auto-trol began building large precision digitizers which were used for civil engineering, mapping and electronic design applications. These were about the size of a drafting table and used an optical technique for tracking the cursor position. During the 1960s I would run into Tammy on occasion at trade shows where the company had a booth and would be demonstrating its digitizers. Around 1970, Auto-trol began interfacing its digitizers directly to minicomputer systems, much like Calma was doing at the same time as described in Chapter 11.

Auto-trol never got much beyond about a million dollars in revenues during these early years and in either 1971 or 1972 the Barnes sold the company to Electronic Assistance Corporation (subsequently known as EAC Industries). In May 1973, Howard Hillman purchased a controlling interest in the company. EAC forgave all the loans it had made to Auto-trol except for $150,000 which was repaid later in 1973 and EAC received 2,000 shares of Series A Preferred Stock and 15,000 shares of Class B Common Stock. Hillman paid $50,000 for two million shares of Common Stock and agreed to lend the company additional funds with which to operate and expand.

Howard Hillman's wealth derived from a large industrial empire headquartered in Pittsburgh, formed early in the $20^{th}$ century by his father, John Hillman. Howard's mother, Dora, married John Hillman and John subsequently adopted Howard and his brother Tatnall who were Dora's children from an earlier marriage. John Hillman, who died in 1959, also had a son from his first marriage, Henry, who is somewhat older than Howard and has run the family business, The Hillman Company, for many years. The Hillman Company was originally involved in heavy industrial commodities such as coke and iron ore including the Pittsburgh Coke & Chemical company but since Henry took over, it has been more involved in real estate development and investments such as Genentech, the first successful biotech company.

 

Dora Hillman established a trust fund for Howard and his family in 1970 known as the Howard B. Hillman Trust. At one time, this trust fund was sufficiently valuable that Howard was listed by *Forbes Magazine* as one of the 400 richest people in the United States with a net worth of over $600 million. While Henry, who stepped down as chairman of the Hillman Company in 2002, is still on the list (#68 and worth $2.8 billion in 2006), Howard and Tatnall, who has a similar trust fund, are no longer listed, which probably suits Howard Hillman just fine. It is the Howard B. Hillman Trust which has provided the majority of the funds over the years used to finance Auto-trol. Without the constant infusion of cash from Hillman and the trust, the company probably would have folded in the early 1990s, if not sooner.

For a number of years, this initial $50,000 outlay looked like one of the most brilliant investments in the history of the computer industry. When Auto-trol went public in 1979 at $14 per share, Hillman's investment was worth $28 million. In the third quarter of 1980, the stock price peaked at $61.50 per share making the $50,000 investment worth $123 million and all the loans Hillman had made to the company up until then had been repaid. It was all downhill from that point. During the next 20 years, Howard invested over $100 million in the company. Most of these funds were initially provided as loans and subsequently converted to equity. In January 2002, the company announced that it was going private at a price which valued Hillman's investment in the company at less than $12 million.

When the company went public in 1979, the name was changed to Auto-trol Technology. It turns out that there was a company in Wisconsin also named Autotrol that manufactured waste treatment equipment. At some point it the late 1980s, this other company actually became an Auto-trol Technology customer.

**Development of early CAD systems at Auto-trol**

When Howard bought Auto-trol, it was being run by John Dzien. Dan McNeil was responsible for sales, Lou Coen was marketing support manager and Peter Skaates was in charge of software development. The first interactive graphic system developed by Auto-trol was Auto-Draft which dates back to 1973. (Although the company's IPO Prospectus says 1970, I believe the company's earlier systems did not support drafting capabilities but were basically computer-controlled digitizing systems.) Auto-Draft was developed as an AEC and mechanical drafting system as differentiated from comparable systems from Calma and Applicon at the time which targeted integrated circuit mask making and engineering design respectively. The first Auto-Draft system was installed at an Alcan (a subsidiary of Alcoa) facility in Canada. Other early Auto-Draft customers included Exxon, Phillips Petroleum, Allied Chemical and Sylvania.

It was no surprise that Auto-trol selected Tektronix storage tube technology for the graphics portion of this system. Nearly everyone else in this new industry was also using Tektronix terminals. What was somewhat surprising, however, was the selection of Varian Data Machines to supply the minicomputer around which these systems were built. The first Auto-Draft systems used Varian's 620/L computer. A typical four station system sold for $250,000. To put a few prices from this period in perspective a 5MB disk cost $16,900, a 40" by 60" flatbed plotter cost $39,600 and a Tektronix 4014 terminal was $21,000. The software was priced at $13,650.

Most of the early systems were used for what can best be described as production drafting. As an example, the system at Phillips Petroleum was used to prepare process flow diagrams, electrical schematics, printed circuit board layouts, assembly drawings and perspective drawings. Phillips claimed that it was getting a 3:1 productivity improvement with this system. Auto-trol sales personnel tended to focus on productivity gains although they sometimes got carried away. I have seen documents where the company claimed that a 10:1 increase in productivity could be expected. While this might have been true for some highly repetitive drawings, it is highly unlikely that such gains could be expected over a wide range of work.

Don Smith became president of Auto-trol in 1974 and several years later he hired Jim Starnes as senior vice president for marketing operations. In 1976, the Sperry Univac Division of Sperry Rand acquired Varian Data Machines. At about the same time, Auto-trol began the development of a new CAD system called the AD/380, which used Sperry's V76 and V77 minicomputers. As best as I can tell, the first AD/380 systems were shipped in 1977. Until the introduction of the CC-80 described below, graphics terminals were pretty much standard Tektronix 4014 devices.

The AD/380 was designed to support up to 12 user workstations and, in fact, the company had installed several with 9 or 10 4014s by early 1979. Auto-trol used a fairly standard version of the VORTEX (V77 Omnitask Real-time Executive) operating system which provided effective multi-tasking with dynamic memory management capabilities. As a result, each workstation could utilize a different software application if desired. One of the key features of the AD/380 was that it could run batch programs in background at the same time it was running interactive graphics software. V77 systems could support up to a megabyte of main memory and a range of disk drives including a 300MB removable disk pack unit manufactured by Control Data Corporation. At the beginning of 1980, the standard computer being used was a V77-600. One problem that continually caused the company grief was that the machine had an optional floating point processor that used a different data format than that used by the system's floating point software subroutines.

By the time I joined the company, Auto-trol had 169 customers with an installed base of approximately 225 AD/380 and Auto-Draft systems. This probably amounted to 1,000 user workstations. A typical system with four workstations sold for about $380,000. That probably did not include the cost of a high-end plotter which could add $40,000 to $50,000 to the price of the system.

In 1976, Auto-trol also began the development of a new graphics workstation called the CC-80. It used a 19-inch Tektronix 619 storage tube display which supported limited refresh capabilities as well as standard storage tube display functions. The CC-80 incorporated a Texas Instruments TI-8800 microprocessor which off-loaded many display tasks from the AD/380 minicomputer. See Figure 9.1.

The CC-80 was one of the finest products ever built by Auto-trol. A significant amount of human factors engineering went into its design. Since CAD systems of that era were designed to be used by full-time operators, motorized height and tilt adjustments were among the features built into the unit. The screen could be raised if it were being used with a digitizer and the operator was standing or it could be positioned for tall or short seated operators.

The CC-80 included a large table on which drawings could be spread out, an alphanumeric display that enabled messages to be displayed without interfering with the drawing being displayed on the storage tube monitor and a 240-button panel called an ACTEC, made up of pressure sensitive switches. These buttons were programmable and typically initiated application-specific functions. The company provided plastic overlays for its different applications. A second optional 240-button panel could be installed when desired. There was also a typical keyboard and a joy-stick cursor control device. Auto-trol began shipping the CC-80 in May 1979 and by the beginning of 1980 had delivered 225 units. The CC-80 sold for $35,000 to $40,000.

Figure 9.1
Auto-trol CC-80 Workstation

Among the other products Auto-trol manufactured was the OPTEC line of digitizers. These were descended from the original products the company had been making since the early 1960s. The OPTEC digitizers came in a variety of sizes and resolutions with and without backlighting. There were two versions, one which used a gantry arm to restrain the cursor while the other was a free cursor model. Another product was the Mark 4 flatbed plotter. This was a monster of a machine. It was built like a battleship gun mount and the joke around the company was that you could ride on the gantry that carried the pens. It was large enough to plot two E-size drawings side by side.

The OPTEC digitizers caused the company few problems compared to the Mark 4. The plotter used a metal band to position the pen carriage horizontally and vertically. These bands were constantly breaking and they were difficult to replace and calibrate in the field. The company spent a disproportionate amount of resources repairing these units.

In general, the AD/380 and the CC-80 were excellent hardware products. There were several problems, however. The most serious from an engineering and support point of view was that every AD/380 system was custom built. Auto-trol purchased basic computers from Sperry and added a substantial amount of its own hardware to each configuration. The design of the system's wire-wrapped back plane was predicated by the specific peripheral devices attached to that system. One result was that it took several weeks to check out a new system and each one had to have the operating and applications software specifically generated for that configuration.

When Auto-trol came out with a new software release, it could not just be copied and sent to all the customers on maintenance. Instead, the company had to perform a

SYSGEN (system generation) operation for each machine and distribute a customized version of the software code to each user. This meant keeping accurate records describing each installed machine, a nearly impossible task. Most of the company's competitors had eliminated the need to do this years earlier by using standardized computer configurations.

Auto-trol was also different than most of its competitors in regards to how it provided basic training. Customers would actually use the specific system being assembled for their company to learn on. Until the company went to more standardized systems, this seemed to work quite well. When companies were paying $125,000 per seat for CAD systems, they were more than willing to send operators to Denver for two or more weeks of training.

**Auto-trol software by 1980**

At the beginning of 1979, Auto-trol was offering two software products, GS-100 and GS-200. GS-100 was an expanded version of the original Auto-Draft software implemented on the AD/380 system while GS-200 was the company's initial stab at creating a mechanical design solution. If an AD/380 system had both suites of software, it was referred to as GS-300. While GS-100 was a very good production drafting package, GS-200 was not ready for prime time. After the company had installed several copies at test sites, it became apparent that Auto-trol had bitten off more than it could chew.

In June 1979 Auto-trol signed a software license agreement with Manufacturing & Consulting Services to use AD-2000 as the basis for a new mechanical design solution to be called GS-2000. See Chapter 15. At the same time, GS-100 was renamed GS-1000 and the combined solution GS-3000. The first GS-2000 installation was made about the time I joined the company at the beginning of 1980.

GS-1000 might well have been the most productive AEC drafting solution then on the market. Over 50% of the installed base of 225 systems was in the petrochemical and architectural and engineering design market space. The company sales organization specifically targeted large petrochemical users. The software had the typical complement of geometry creation and editing functions then found on competitive systems.

GS-1000 used a command language for determining user operations. As an example "R" stood for rectangle and "CC" for circle. Each command had a number of options. For example, with the circle command the user needed to tell the software how the circle was to be defined (center and radius, three points, etc), what line type was to be used for the circle and how the coordinate values were to be defined (keyed in or screen selected). Once a command option was defined, the system would use that information until the operator entered a change. Some commands, such as dimensions, were very extensive with as many as a dozen options.

A complex command, or even a series of commands, could be made part of a macro called a Quick Action and assigned to a button on the ACTEC panel or to a button on a digitizer menu. While it took users up to six months to become proficient with this command language, once they did, they were extremely productive. When you watched some of the company's better application engineers doing demonstrations, their hands were a blur moving over the keyboard.

GS-1000 supported 256 data layers which was a competitive advantage over M&S Computing (Intergraph) since that company's software supported just 64 layers.

 

The software also did an excellent job inserting crosshatch patterns. GS-1000 came with a large set of such patterns. When Autodesk introduced AutoCAD several years later, that software's set of crosshatch patterns was virtually identical to what Auto-trol had been providing for a number of years. The company also provided fairly extensive sets of application-specific symbols.

What really separated GS-1000 from the competition was the Quick Action macro capability. One of the advantages of a command language system over a pure menu-based system is that it is easier to implement a powerful macro capability without it having to be a separate language. A GS-1000 Quick Action or QA could be as simple as a single command or it could contain hundreds or even thousands of steps that would create entire drawings. One customer created a complex QA that literally designed an entire steel rolling mill based upon data the operator entered. Two important aspects of QAs were that they could pause for operator input and that they could be nested much like software subroutines. QAs were a key tool used in developing industry-specific applications.

While GS-1000 was a fairly powerful drafting tool and one Auto-trol could be proud of, the company was quite weak in regards to industry-specific applications. There were a few applications for process plant piping design and electrical schematics as well as a limited architectural floor plan package and some mapping software. One area where Auto-trol had made good progress was in creating a package for technical illustration that was initially called ATIPS. This was one market segment the company has been strong in for over 25 years and one of the few drafting-specific applications it still supports as this is being written.

**Product development in the early 1980s**

Auto-trol grew from $1.4 million in revenue in 1975 to $50.8 million in 1980. The basic AEC drafting product was solid and the company was sufficiently profitable that there was money available to develop a viable mechanical product line if it was done wisely. The company had gone public a year earlier and its stock had more than doubled since then. Don Smith ran the company on a day-to-day basis as president with Hillman visiting Denver from his home in Connecticut every couple of months.

Smith had hired Jim Starnes several years earlier to run the sales and marketing side of the business. In 1979 Starnes began a fairly blatant effort to replace Smith as president. Starnes felt that the company needed to move more aggressively in developing a raster display capability and in moving into more advanced application areas such as mechanical and electronic design. He quietly began lining up internal support to become president. Just before I joined the company, Starnes made his pitch to Hillman who responded by recommending to Smith that he fire Starnes which he did. Starnes went on to start Graftek in Boulder, Colorado, taking a number of Auto-trol employees with him as described in Chapter 21.

Mike McGarr had been brought on board in late 1979 from Varian to be executive vice president of internal operations. In early 1980 Smith hired Graham King as executive vice president for field operations, filling the vacancy created when Starnes was fired. Graham's brother, Bob King, was on the company's board of directors. While on the surface this looked like a good move because King had 15 years of significant sales management experience at IBM. In retrospect it laid the foundation for the gradual disintegration of what could have been a dominating company in the CAD/CAM industry.

As described below, a major factor impacting Auto-trol was the influx of former IBM sales and marketing managers – John Rodgers, Jim Hammock, Gene Barduson, Joe Zemke and others. Even Don Smith was ex-IBM. A number of sales managers in the field including Jim Norrod and Dave Hanna were also brought on board from IBM. They were all good, smart individuals. The problem was that they believed sales and marketing could overcome any product deficiencies a company might have. This was towards the end of an era when people in the computer industry were fond of saying, "on any given day IBM could swap product lines with UNIVAC and within a year, IBM would be back on top."

One of the byproducts of this focus on sales and marketing, particularly sales, was that new product development did not receive the resources it needed. Perhaps the biggest problem was that the company was excessively focused on the manufacturing aspect of its business. In fact, a few days after I started work, Don Smith told me in no uncertain words to "remember, this is a manufacturing company." Until 1980 this probably made considerable sense. The margins generated on internally manufactured products served to fund the software development then underway. Software was really a mechanism to help sell more hardware.

Figure 9.2
Auto-trol meeting in Scottsdale, AZ, January 1980
Clockwise from lower left: Mike McGarr, Bob McFarland, Dave Weisberg, Graham King, Don Smith, Art Minich
(Note business dress even though this was a weekend off-site meeting)

**V77-800 computer transition**

A fairly complex project in 1980 was the introduction of the Sperry Univac V77-800 minicomputer as a complement and eventual replacement for the V77-600 that had been used up until then to power most AD/380 systems. The first new unit was shipped in early June 1980. The V77-800 was perhaps one of the best 16-bit minicomputers ever manufactured from a performance point of view. Unfortunately, Auto-trol was the only company using the machine for CAD systems and the company was not able to obtain much marketing support from Sperry.

While the AD/380 had been designed from the start to support up to 12 workstations, the reality was that the V77-600 did not have the horsepower to support more than about six without adversely impacting performance. The V77-800 provided the power that enabled the company to sell larger systems. In June 1980, Auto-trol shipped several systems worth over $600,000 each and one that sold for over $700,000.

While Auto-trol was in the process of introducing the V77-800, the company realized that it had to move to the new generation of 32-bit minicomputers which were becoming increasing prevalent for engineering design systems. A major activity throughout 1980 was the evaluation of available computer systems from companies including Sperry Univac, Digital Equipment, Data General, Systems Engineering Laboratories, Prime Computer and Interdata (Perkin Elmer). Eventually, the company decided to go with the Digital VAX product line.

**Planning the future of GS-1000**

A major project at the same time was determining the future of GS-1000. This software package was primarily written in assembly language for the V77 product line. The company kept looking for a way to convert the code to FORTRAN without having to manually rewrite it. Several questions Auto-trol struggled with for months were whether or not to create a 16-bit V77 FORTRAN implementation or to concentrate on developing a 32-bit version for whatever new computer platform the company selected and the extent to which the new software had to be compatible with the existing GS-1000 program.

In the later area, there was no question that the new version had to be able to import drawing files created with GS-1000. Whether the new files had to be backward compatible with GS-1000 was a different question. It would be a more difficult task to accomplish the latter and the company did not know how important this capability would be for its existing customers. Auto-trol eventually decided to make the new software backwards compatible as well. It proved to be a difficult task and several key users later told the company that it really did not have to be done. By then it was too late. One important decision was that the new program would be able to execute existing QAs without modification. That turned out to be a smart decision.

**Mechanical design software**

Auto-trol's mechanical activity, especially in regards to software development, was in turmoil in 1980. The initial development was done under the direction of Ron McElheney who had hired a fairly large staff in a period of just a few months. While Auto-trol produced several GS-2000 brochures in 1980 it is not clear how much of the software was really working on the AD/380. Most of the illustrations in the company's early brochures appear to be standard AD-2000 screen shots produced by MCS.

In early 1980, McElheney left to go to work with Jim Starnes at Graftek, taking several of the GS-2000 programmers with him. The development group subsequently was managed by Dave Custer, reporting to Art Minch who had replaced Ed Vrablick as vice president-software sciences. Custer had a crew of about 15 people, few of whom had any prior experience working with three-dimensional mechanical design software. Most of the effort actually went into programming an AD-2000 interface for the CC-80 workstation along with adapting AD-2000 to the other AD/380-specific hardware components.

**Management changes**

Around mid-1980 several management changes occurred at Auto-trol. Gene Barduson, who had been brought in by Graham King as director of national accounts, became director of marketing programs. The title was a misnomer since Barduson's focus was almost entirely on the mechanical market. During the next year or so, he built up an impressive marketing staff - Jim Newcomb who went on to become a senior manager at Dataquest, Dave Burdick who has had a significant career as an industry analyst at Dataquest and Gartner as well as an independent consultant, Walt Simpson who joined Auto-trol from Computervision and Terry Bennett who also ended up as an industry analyst.

The other change was to split mechanical applications development off from AEC application development. Auto-trol tended to treat application development as a marketing function rather than as an R&D activity. Dick Burkley was brought in to run the mechanical side of this activity. He had been working at IBM on its CADAM software when Auto-trol hired him. Burkley brought with him a level of software management expertise that the company sorely needed.

In another move around mid-1980, Bob McFarland, who had been national sales manager before John Rodgers and was now director of marketing moved to London to run the company's European operation. As noted earlier, Auto-trol's sales and marketing activities were taking on a very IBM look and McFarland, apparently, did not fit the mold. He would stay in Europe for about a year at which point, he was replaced by Rodgers.

The biggest change, however, occurred on August 14, 1980 when Graham King replaced Don Smith as president and CEO. Although Smith was expected to stay on for a while as chairman of the board, he soon relinquished that position. King recruited a friend from his IBM days, Joe Zemke, to replace him as executive vice president of marketing.

**A missed opportunity**

The computer industry is full of stories about missed opportunities. If only company X had done such and such, its future might have been significantly different. In the fall of 1980, Auto-trol had an opportunity to radically change its future and passed. The situation involved Jim Clark, the founder of Silicon Graphics and Netscape.

Bill Brett, Auto-trol's vice president of engineering had become aware of work being done at California Institute of Technology and Stanford University on the design of advanced integrated circuits using methodologies developed by Carver Mead. Clark was associated with Mead and had some ideas for creating a new generation of graphics processing circuits using Mead's techniques.

Brett invited Clark to visit Auto-trol one weekend. I remember the meeting clearly because we met that Saturday at my condo. I had previously arranged to have furniture delivered that day and had to be there. We basically put together the outline of a business plan for the development of a new generation of graphic systems. The idea was to set up a separate entity in which Auto-trol and/or Hillman separately would invest and Auto-trol would take the resulting product to market. I was not involved in pitching the concept to Hillman - Brett handled that task. Auto-trol never funded Clark's idea and he eventually went off and started SGI using roughly the same concepts we had discussed that weekend.

Years later Hillman was asked why he didn't go along with the plan the three of us had worked up and his response was that it proved to be impossible to pin down what Clark would be responsible for and what Auto-trol would be responsible for. My personal opinion is that the two of them simply couldn't work out a mutually agreeable financial arrangement. Auto-trol then went on to invest several million dollars in developing a new generation of graphics terminals, products that mostly never made it to market.

**Rationalizing Auto-trol's products**

By mid-1981, Gene Barduson was responsible for the company's mechanical software products. At some point (it could have been earlier in 1980) Auto-trol decided that working with MCS on updates to AD-2000 was becoming impossible and that the company would be better off taking full responsibility for the source code. The problems with MCS were a combination of business and technical issues. For a lump sum payment of $1 million, Auto-trol received the latest version of the AD-2000 source code and full rights to resell it to end users.

While GS-2000 was struggling to gain market traction against companies such as Computervision, Applicon and Calma, GS-1000 was holding its own in the AEC market primarily against Intergraph and to a lesser extent, Computervision. It was becoming increasingly obvious, however, that GS-1000 was loosing its technical edge and that a new 32-bit version written in FORTRAN was the way to go.

Although few in the company admitted it at the time, the lack of a color raster display was also becoming a severe sales detriment. In 1981, machine-independent software was not a well-accepted practice (AD-2000 was an exception) and most software was written for specific computer systems. The initial plan was to develop the new version of GS-1000 for the Digital VAX.

Implementing GS-2000 on the VAX was not a major challenge since the software had already been ported to that machine by both MCS and Tektronix. The major task was developing the interface to the VAX for the CC-80 terminal.

It is interesting to note that in its July 6, 1981 issue, *Business Week*, ranked Auto-trol 4th in the nation in regards to the percent of revenue spent on research and development. We were spending 12% on R&D. That sounds low by today's standards for high tech companies, but in 1981 it was significant. Auto-trol ranked 3rd in terms of actual dollars per employee spent on R&D, $9,277. In retrospect, Auto-trol may well have achieved its high rating because it included as R&D charges items many other companies allocated to other expense categories.

 

**The first of many layoffs**

During most of 1981, it appeared that Auto-trol's sales were holding up fairly well. Unfortunately, the company had put an expense budget in place that required a even more substantial growth in revenues than what was occurring. Shortly before Labor Day the decision was made that the company would have to reduce staff by 15 percent. This would turn out to be the first of many such layoffs over the years.

The cutbacks led to a moderate reorganization of sales and marketing. AEC application development had been run by Clair Johnson, an extremely outgoing manager who portrayed a cowboy image complete with black cowboy hat and boots. To be as objective as possible, he was in over his head technically and his people did not particularly like working for him. He was one of the few managers let go during the layoffs, ending up a few months later as director of sales and marketing at MAGI, a graphics visualization company. Jim Hammock, who was vice president of marketing, asked me to take over this department as part of the reorganization.

This was a confusing period of time for Auto-trol. The company had started rewriting GS-1000 for 32-bit computer systems but AEC application development was still being done for the 16-bit Sperry V77-600 and V77-800 systems. At the time, the new CAD software was called GSX but was eventually marketed as Series 5000. Some of the other projects underway at the time are described below.

**Exploration Mapping –** Over twenty years later, derivatives of this software are still in use around the world in the form of a package Auto-trol calls GEOSTATION. Most mapping-related programming at the time was being done at that time by a single individual, Bill Adams, with only a small amount of assistance from other programmers. The primary focus of the mapping software was to assist oil and gas exploration organizations in keeping track of seismic survey and well data. These were often quite large data files covering extensive geographic areas. GS-1000 was particularly well suited for handling this type of information.

Adams had a rather novel idea for managing map data. Up until then, most mapping application done with CAD systems involved storing spatial data as CAD geometric entities and related data as attribute tags. GS-1000 did this about as well as any competitive systems then on the market. The problem was that large maps had to be divided into a number of separate files, each representing a single map sheet. When an area that covered portions of several sheets had to be displayed, the process was both difficult to accomplish and typically very time-consuming. Adams' idea was to store both the spatial data and the attribute information in a database and simply generate views of this data based upon what the user desired to work with at a particular point in time.

He called this "throw away graphics" since the displayed images were not saved, just the underlying database. It was an efficient technique, even considering the overall performance of the V77 systems the company was using at the time. The most comparable competitive system was probably Intergraph's. They had a database application, DMRS, that was closely linked to their interactive graphics software, IGDS. The difference was that spatial data was stored in IGDS and only attribute information was stored in DMRS. Where Auto-trol had strong sales and technical support such as in Calgary, Canada, the company was able to compete effectively with Intergraph. For many years, the company's exploration mapping software was the best selling Auto-trol product in Canada. Eventually, its development and support was moved to Calgary.

**Architectural Design –** By today's standards, Auto-trol's architectural design software was extremely crude. It could just do basic floor plans and disassociated elevation drawings. In spite of the fact that GS-1000 was nothing more than a power drafting system, there were a number of large architectural firms using it.

For several years the company put significant resources into developing architectural space planning software. The concept was that an architect would be able to define which groups needed to be near each other and which did not. As an example, the CEO's office needed to be near the board room but neither needed to be near the cafeteria.

The software would analytically determine an optimum floor plan layout. Although it sounded like a natural application for GS-1000, it proved to be a more difficult program to write than initially contemplated and the market for this type of software never really developed. The architectural drafting software, on the other hand, eventually turned into a fairly decent product called PLAN, once Series 5000 matured.

**Drafting Utilities and Schematic Drawings –** One success story was Auto-trol's introduction of a set of drafting utilities called A-PLUS, developed by Dave Peverley working with Chris McGary. As mentioned earlier, one of the strongest features of GS-1000 was its Quick Action capability. A-PLUS consisted of a set of QAs that facilitated production drafting. It was a fairly simple concept yet it was the first time that these functions had been pulled together in a package that was made available to all users.

In late 1981 Auto-trol established a relationship with Jim Fox, an independent software developer living in the San Francisco area. Fox had developed some useful GS-1000 software while working as a contractor for Exxon including a package for doing electrical schematics and process and instrumentation diagrams (P&IDs). Auto-trol worked out an agreement with Fox under which the company would sell this software renamed RAP-EL and RAP-ID and pay him a 50% royalty.

The assumption at the time was that this would be an interim solution until Auto-trol could develop its own packages in this area. In retrospect, the royalty rate was far too high and the packages needed substantially more cleanup and documentation by Auto-trol than the company had contemplated. But Auto-trol needed software in this area fast and this was one way to get there. Those of us involved at the time never expected that ten years later Auto-trol would still be selling Fox's software and paying him substantial royalties.

In the late 1990s Fox sued Auto-trol claiming the company owed him a substantial amount of money, particularly in regards to maintenance revenue it had collected from numerous government accounts. Eventually, the judge threw out the case because too long a period of time had transpired before Fox sued.

 

**Structural Steel –** In the late 1970s Auto-trol sold an AD/380 system to Bancroft & Martin in South Portland, Maine to do steel detailing[1]. They developed some rather good GS-1000 software to handle detailing functions. The two companies worked up an agreement under which Auto-trol would take Bancroft and Martin's software and productize it. Soon thereafter Auto-trol set to work planning the development of a suite of steel applications that would include the design of steel frameworks, the interface to analysis software, the design of connections and structural detailing.

In mid-1982, Joe Zemke had a meeting with Don Greenberg of Cornell University who was well known for his pioneering work in visualization software. Zemke and Greenberg hit it off well and soon Greenberg was in the process of developing a structural steel design package for Auto-trol. It was very well done with an excellent user interface and it put an end to any internal work in this area.

Called Steel-3D, this package was only loosely connected to the company's basic AEC CAD software - what eventually became Series 5000. A follow-on package for designing concrete foundations called Foundation-3D was also produced by Greenberg's team. There was one major problem with Steel-3D – it only handled steel members at a time when customers wanted a structural package that would do reinforced concrete components as well. While the initial software was well done, the informal agreement Zemke had worked out with Greenberg did not call for the level of follow-on activity that was really needed to make the package successful.

One major user of STEEL-3D was Qwens-Corning Fiberglass which used the software to design factory structures. According to Robert Schaefer, who was responsible for installation of the system at OCF, STEEL-3D resulted in saving about 20 percent of the weight of a building's steel framework. At $2,000 per ton for structural steel in the mid-1980s, this meant a savings of about $60,000 on a 100,000 square foot manufacturing building.[2]

The company Greenberg put together to develop STEEL-3D was called 3D/EYE. In the mid-1990s this company introduced an excellent conceptual design software package called TriSpectives which subsequently became IronCAD. (See Chapter 21.)

**Process Plant Design –** In the early 1980s, by far the largest market sector for Auto-trol was in process plant design. The company had numerous customers among engineering design and construction firms including Bechtel, Brown & Root and Haliburton as well as the operating companies themselves including Exxon, Shell and Air Products. Most of these customers were using GS-1000 for production drafting. The company offered a few industry-specific applications including an orthographic piping design package which was really little more than a sophisticated symbol library. It did include checking features that ensured that components such as valves, flanges, tees, etc, were compatible with the elements they were connected to.

For some time, Auto-trol had been attempting to define and develop a comprehensive plant design package. One of the company's problems in this area was that Auto-trol had virtually no marketing or technical people who understood plant design

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[1] How small a world it is. Bancroft & Martin was my sponsor for an American Association of Steel Construction scholarship I received in 1955 and I worked in there drafting department the summer of 1957.

[2] Schaefer, Robert S. – *Integration of Structural Steel Design* – "The C4 Handbook: CAD, CAM, CAE, CIM – Carl Machover, Editor, TAB Books, Blue Ridge Summit, PA, 1989

 

at a high level. This was solved when Jim Hammock hired Tom Curry[3] who had been manager of design engineering at Air Products. Curry came on board in late 1981 and set about defining what a real plant design solution should look like. He subsequently hired as a consultant Michael Leesley who had previously been responsible for process plant software development at Computervision and was the editor of *Computer-Aided Process Plant Design*, a massive 1,378-page tome covering everything from computer architecture to piping analysis. Leesley was hired as a consultant to advise the company on how it should proceed with developing a state-of-the-art process plant design system.

In 1982, Auto-trol decided to have a new company Leesley had established in Texas develop a plant design system from scratch. It was to be funded through a research partnership arranged by Hambrecht & Quist in which Howard Hillman put up some of the money. It was funded to the tune of about $7 million dollars. The rationale behind this form of funding was to isolate Auto-trol from the quarterly R&D expenses involved. Eventually, Auto-trol would market the software and the expectation of the investors was that the company would then buy them out at a nice profit.

Doing plant design development outside the mainstream of the company's R&D organization proved to be very disruptive to the internal organization. Auto-trol made a costly acquisition of another CAD software company, Tricad, to provide technology that top management perceived could not be developed internally. Leesley proved to be inept at managing a large project and the partnership was eventually terminated with no useful software resulting. As a consequence, Intergraph soon began taking away much of Auto-trol's process engineering business and by the late 1980s, the company had little new business in this sector.

**Apollo and Series 5000**

In 1981, I began to read about a new computer company, Apollo Computer, that had been founded in 1980 by an MIT classmate, Bill Poduska. Auto-trol's engineering department had been working on the design of a stand-alone graphics system with emphasis on high performance graphics. Apollo's system was similar to what Auto-trol was working on except that Apollo incorporated the concept of networking their machines together in what it called a token ring architecture.

In October 1981, a group of Apollo managers including Bill Poduska visited Auto-trol and pitched their new system. My reaction and that of several other Auto-trol managers was that with a few changes, this was just what we were looking for and that it would separate Auto-trol from other CAD companies that were concentrating on using Digital VAX minicomputer systems. The biggest shortcoming of the Apollo hardware at that time was its relatively weak graphics capability. Our thought was if we combined Auto-trol's graphics expertise with Apollo's computer and networking expertise we would have a great system. Within a few months, Auto-trol became one of Apollo's first significant OEM customers.

Porting the GS-2000 mechanical design software to the Apollo platform was not a major task and at the 1982 NCGA conference in Anaheim, California, the company was able to show a prototype of what was now called Series 7000 in operation. It was the hit of the show. Meanwhile, development of Series 5000, the eventual replacement for GS-

[3] Curry later worked for McDonnell-Douglas running its AEC CAD business. He then went to PDA Engineering, becoming that company's president and eventually president of MCS after it acquired PDA.

 

1000, was proceeding at a reasonable pace and it was decided to initially implement the new software on the Apollo platform rather than the VAX. Don Zurstadt was the Series 5000 project manager for this effort.

At this point in time, the Auto-trol management team consisted of:

Graham King – president and CEO
Joe Zemke – executive vice president
Jerry Sisson – vice president/international
Gene Barduson – vice president/sales
Jim Hammock – vice president/marketing
Paul Jerde – vice president/finance
Carnig Izmirian – vice president/field engineering
Bob McFarland – vice president/international
Art Minich – vice president/R&D
Bill Taylor – general council

**European joint venture**

In 1981 Auto-trol established a joint venture with an Italian company, Selenia, to handle the sales and support of the company's products throughout Europe. This joint venture basically took over all of Auto-trol's then existing European operations which really were not much. Denny Chrismer was sent to Italy to be Auto-trol's full-time representative in the joint operation. Although Selenia was headquartered in Rome, the joint venture operated out of Genoa.

**Auto-trol's product line in the mid 1980s**

From 1983 through 1985 some of the key development projects included the following:

**Advanced Graphics Workstation (AGW) –** As mentioned earlier, Auto-trol's most visually recognizable product was its CC-80 series of workstations as shown earlier in Figure 9.1. When Auto-trol signed an agreement to OEM Apollo workstations, the company's initial reaction was to maintain the continuity of these workstations by simply replacing the original Auto-trol manufactured control logic with the Apollo computer and graphics controller. The result was a highly productive workstation that was, unfortunately, significantly overpriced for newly emerging market conditions. Eventually, Auto-trol decided that standard Apollo workstations were more price competitive than the repackaged AGW.

**Advanced Raster Workstation (ARW) –** Before selecting the Apollo platform, Auto-trol had decided to port its software to Digital's VAX computer. For this, the company needed a color raster workstation. Initially, the plan was to develop its own raster graphics capability. This work proceeded rather slowly under Bill Brett's direction with much of the design work done by Mho Salim and Jerry Peterson[4]. Eventually, it was decided that third party technology would be a better route to take and the company signed an OEM agreement with Raster Technology in August 1982 to incorporate that company's graphics hardware in the ARW.

[4] Peterson left Auto-trol to work with Art Minch at Tektronix and then went to work for Intergraph, eventually running that company's graphics product line until it was sold to 3D Labs.

 

**Advanced Personal Workstation (APW/15**) **–** In an attempt to provide Series 5000 software on a PC, Auto-trol created a hybrid system that consisted of a UNIX co-processor installed in a MS-DOS PC. The objective was to minimize Auto-trol's programming effort in providing a PC solution. The product was introduced in mid-1985 but never sold in any significant volume. Bob Stevenson, who was responsible for this project, in a recent interview, stated that the major problem was that Hillman insisted that the price be about twice what Stevenson thought the market would support.

**Series 5000 –** This new graphics system was initially released in 1983 and received good reviews from Auto-trol's customers. Most were impressed with the compatibility maintained with older GS-1000 systems and with the software's performance and geometric accuracy. Dave Peverley put together some excellent demonstrations to illustrate the effectiveness of 32-bit data structures. One major problem was that so much effort had gone into developing Series 5000 that there were few resources available for creating new applications that would take advantage of the software. Auto-trol had no concept of working with third party application developers as did Autodesk and did not realize, at the time, the strategic handicap this would be.

**Plant Design –** The research partnership with Michael Leesley to develop a Process Plant Design (PPD) system was formally launched in early 1984. It started badly and went downhill from there. The basic concept was excellent, comparable to products subsequently sold by Intergraph, CADcenter, Bentley and Rebis. Tom Curry and Michael Leesley put together an extensive business plan for the PPD in December 1982. The problem was not in the concept which was excellent but in the execution of the plan.

It probably didn't help that it took over a year from publishing the PPD plan to actually starting work on its development. Leesley hired one experienced plant design software manager from Calma, Malcolm Hall, but most of the rest of the team he put together in Austin, Texas had little experience in this area. There were also some problems with Leesley's management style. According to Curry, Leesley was a little too much of an empire builder and was focused more on personal issues such as a new house he was building in Austin than concentrating on the project.

This lack of plant design experience was compounded by two bad decisions. First, they needed a relational database management package. After surveying what was then available, the team, including Auto-trol personnel, selected EMPRESS. This was not a bad database product, it was just very immature and EMPRESS never gained much marketplace traction. Unfortunately, Auto-trol decided that it would also use this database package for other application development. A lot of things might have turned out differently if the company had selected a more popular database product such as Oracle or Informix.

The second mistake was the decision not to build the plant design solution around Series 5000 but to acquire Tricad as described below. Although this project was supposedly "off the books" because of its research partnership structure, it had a major impact on other activity at Auto-trol. As an example, Dick Burkley spent nearly a year assigned full time to the plant design project, taking him away from important mechanical application development work.

Eventually, Auto-trol and the investment people at H&Q decided to pull the plug on the research partnership. They were a long way from having a workable solution and the money that was left would not have covered what still needed to be done. Some of the work done in Austin was salvaged and was used in developing VectorPipe, a product Auto-trol still sells in Europe.

**Tricad –** This was an AEC software company Bill Hambrect from H&Q was involved with. Altogether, the VCs had invested $7.7 million over four years. Auto-trol purchased the company for about $2 million in stock in early 1985. Tricad, which at its peak had 65 employees, was down to 15 people when Auto-trol took over. The company's head of R&D was Roger Sturgeon who had previously worked at Calma. Tricad put together a building design solution that was one of the first to incorporate object-oriented software concepts. Although Auto-trol made the acquisition, the intent was almost entirely to support Leesley's plant design software project. Tricad had about 20 customers at the time of the acquisition, few of whom remained Auto-trol accounts once they were told that the Tricad software would no longer be supported.

There was one exception. Tricad had sold its software to the U. S. Army at Fort Huachuca, Arizona to do communications network engineering. Dave Hanna thought this was a great business opportunity for Auto-trol and a huge amount of effort was spent in 1985 and afterwards trying to develop a viable communications engineering business for the company. The basic Tricad software was called G-3 while the communications engineering software built on top of it was called TEAMS (Telecommunications Engineering and Asset Management System). One of the few Tricad people who stayed with Auto-trol was the salesman on the Fort Huachuca account, Bud Broomhead.

**Mechanical Design –** In general, Auto-trol never seemed to be able to generate as much traction in the mechanical CAD area as management had hoped. GS-2000 was renamed Series 7000, the software was ported to the AGW and applications such as sheet metal design and finite element modeling were added to the original AD-2000 software. By late 1983, Series 7000 and related applications made up nearly 60% of the company's system business.

Auto-trol also licensed a solids modeling package that was only loosely tied into Series 7000. Some aspects of this software, particularly the company's ability to edit NC tool paths was as good as anything the competition offered. The short-term relative success of the mechanical product line was partially due to the fact that few AEC applications had been ported from GS-1000 to work with Series 5000 as of late 1983, slowing sales in that market for a period of time.

**Steel-3D –** Although this was perhaps the most visually attractive AEC application Auto-trol had, the company was not able to use it to leverage a significant volume of new systems business. The lack of concrete design capability was one factor but the high price was probably a bigger detriment.

**MOSS –** In the latter part of 1985 the AEC marketing group negotiated an agreement with England's MOSS Systems to market their civil engineering design software in North America. This was an excellent package except that it was primarily a batch computer program at the time. MOSS Systems agreed to develop an interactive interface and the Auto-trol people took on the responsibility of integrating it with Series 5000. This took a year or so to accomplish.

**Mapping –** The oil well posting software described earlier was probably the best internally developed application the company had during this period. Auto-trol had acquired its Canadian distributor, CANDRAFT, several years earlier and under Ken Dedeluk, it was doing very well selling this package in Calgary.

 

**More management changes**

Auto-trol went through its share of management changes during the early to mid 1980s. In November 1982 Hillman fired Graham King[5] and Joe Zemke took over as president. Terminating King cost the company over $800,000 to settle outstanding stock options and other obligations. A few months later Jim Norrod became vice president of U.S. sales. Few people have had a more immediate impact on a company's sales momentum then Norrod did. He was an incredible bundle of energy who got everyone moving at a faster pace. The results during the next several years were impressive.

After he left Auto-trol in 1986, Norrod became president of CGX , a manufacturer of IBM 5080-compatible graphics terminals eventually acquired by Adage. Subsequently he was president of Tellabs and several other high tech companies. In March 2005, he became president and CEO of Segway, Inc., the company formed by Dean Kamen that manufactures the Segway Personal Transporter.

The biggest problem with Zemke running Auto-trol was that it was simply too small a company for his style. His training at IBM had prepared him to run an organization where he had a much larger support group than he had at Auto-trol.

On February 28, 1985, I traveled to Santa Clara, California with Zemke to visit Sun Microsystems. At the time, Auto-trol was considering switching from Apollo to Sun or at least complementing the Apollo portion of the company's product line with a Sun option. We spent much of the day with Scott McNealy and other Sun executives (at that time it was a 900 person company doing about $120 million annually).

Late that afternoon I drove Zemke to the San Jose airport, supposedly to catch a plane while I went off somewhere else, probably another meeting in the area or in San Francisco. Zemke never told me where he was headed probably because he was not going anywhere. Instead he rented another car and went to an interview with Amdahl. Shortly after returning to Denver, Zemke announced that he was leaving Auto-trol to become president and COO of Amdahl at a salary of $600,000 per year or about three times what he was making at Auto-trol. Within a few months Jim Hammock also left Auto-trol for greener pastures in California.

In less than five years Auto-trol had gone through three presidents, all of them ex-IBM executives. Hillman decided that before he hired another president, he was going to spend more time in Denver and temporarily run the company himself for a few months. Twenty years later he is still in Denver running Auto-trol although he stopped referring to this as a temporary assignment many years ago.

In either October or November 1985, Jerry Sisson asked me if I would undertake the task of establishing a marketing activity to support the company's business of selling systems to federal government agencies. His idea was to model what we would do after the government systems group Sun Microsystems had set up under Carol Bartz who subsequently became president of Autodesk in 1992.

It became apparent fairly quickly that there was considerable potential federal government business available and that the competition was fairly well defined. In the mechanical area the primary competition was Computervision with secondary competition from Calma and a little from Applicon. In the AEC area the competition was primarily from Intergraph with secondary competition from McDonnell Douglas.

[5] King subsequently became president of Shared Medical Systems

Autodesk was not yet a factor having just begun shipping PC-based software. Many government agencies which had purchased relatively small first or second generation CAD systems and were now preparing for major expansions of these systems.

### Auto-trol under Howard Hillman

Gradually, Auto-trol began to replace the early AGWs which had the Apollo computers repackaged in CC-80 consoles with standard Apollo computer systems. At this point, the company decided to offer its software unbundled as well as bundled with computer hardware. Auto-trol charged a premium of $3,000 to $5,000 for unbundled software to offset the lost margin that resulted from not selling the hardware. At the time, a number of other companies did the same thing and customers seemed to go along with it at first. Auto-trol also had work underway porting its software to run on Sun workstations.

Auto-trol software, including applications as well as Series 5000 and Series 7000, was licensed for a specific piece of computer hardware. These licensing arrangements were controlled by using encryption keys tied to the identification code of the hardware. This made it difficult for users to move applications from one network node to another. Also, when customers purchased a new Apollo computer, they could not move the software to the new node without Auto-trol's permission.

The company saw this as an opportunity to generate incremental revenue and the list price for a license transfer was $5,000. This was a hard sell since most customers thought that they had purchased a perpetual license for the software. They had, as long as they wanted to run it on obsolete hardware. If one tries to identify all the little things that eventually led to Auto-trol's demise, this was a contributing issue. Within a few years customers would look at the $5,000 license transfer fee and decided that they could get along with AutoCAD rather than Series 5000 and save several thousand dollars in the process.

One of the other pricing problems involved software maintenance. Auto-trol had quantity discounts for software that were actually fairly aggressive. In quantities of 12 or more seats, unbundled Series 5000 had a list price of $11,500. The company was much more reluctant to discount software maintenance, however. Auto-trol had three different service zones depending how far the customer's site was from an Auto-trol field office. The software maintenance cost for Zone III was over $350 per month per node or $4,200 per year just for Series 5000. Either of two things resulted from such steep maintenance pricing, the prospect selected a competitor once they considered multi-year costs or Auto-trol ended up with unhappy customers who felt they were being ripped off.

### Government sales activity

In the late 1980s, one bright spot for the company was the success it had selling both AEC and mechanical CAD systems to government agencies at the local, state and federal levels. Some of Auto-trol's major government accounts included:

**Western Area Power Administration (WAPA) –** Like many other government sales opportunities over the next few years, the incumbent vendor at WAPA was Intergraph. The major complicating issue on this deal was the need to include an X.25 packet switching communications system. Curt Loomis, the salesman on the account, identified communications equipment from GT&E that would handle the task and the company incorporated it into its proposal. It was probably a $150,000 portion of what turned out to be a $4.2 million contract. It was the first time Auto-trol took on this type of systems integration work.

Another issue, as it would be in numerous accounts for the next several years, was that the Request For Proposal (RFP) was oriented around a minicomputer-type solution and Auto-trol had to justify that its Apollo workstations were an equal or better approach. The proposed Series 5000 system included a major installation at WAPA's Denver facility and smaller systems, some just a single workstation, scatter around most of the West other than California. Altogether, the initial contract in late 1986 was for 29 AGW/22 workstations and 15 NSP/32 servers at 13 separate sites. It included options for 50 additional workstations that had the potential to add another $5 million to the contract value. WAPA never executed all the available options although it did order a significant number of additional workstations from Auto-trol.

WAPA was Auto-trol's first big win in the government area. They told Loomis that we had won but not to make the fact public until they released the information to the press. Loomis, Hillman and I went out to WAPA's office in the Denver West Office Park to witness the signing of the contract. When we got back to Auto-trol, Jerry Sisson called all the employees together for a company meeting in the cafeteria. Everyone thought there was another layoff coming and they were extremely pleased when he announced the largest contract award in the company's history.

Figure 18
Western Area Power Administration Contract Signing

*Seated: Don Ray, contracting officer, Western: standing (I-r ): Curt Loomis, senior account manager, Auto-trol; Tom Weaver, assistant administrator for engineering, Western; Bill Clagett, administrator, Western; Howard Hillman, president and chairman of the board, Auto-trol; Dave Weisberg, director of Federal Systems Group, Auto-trol; and Will Jacoby, chairman, technical evaluation panel, Western*

 

**U.S. Air Force Logistics Command –** Auto-trol had installed its technical illustration software at Hill Air Force Base under a subcontract to Syscon, a San Diego-based system integrator. That project, which involved automating the preparation of aircraft maintenance manuals, was called ATOS or Automated Technical Order System. A Technical Order is the way the Air Force describes a maintenance manual. Similar systems were subsequently installed at other Air Force logistic centers. Separately, the Air Force Logistics Command initiated the procurement of a mechanical CAD system. Auto-trol responded to the RFP and won a $1 million contract by just $4,000 with Calma as the runner-up.

The Air Force proposal was complicated by the fact that the company had to include finite element analysis software as part of its bid. Auto-trol's intent to bid NASTRAN from MSC for the FEA portion of the contract was further complicated by the fact that this was a fixed-price lump-sum contract and MSC licensed its software on an annual fee basis. They eventually agreed to a lump sum cost for bidding purposes which was key to Auto-trol being compliant. The contract included a clause that allowed five other Air Force logistic centers to procure systems off the same contract. By the end of 1989, Auto-trol installed nearly 140 Apollo workstations running either Series 5000 or Series 7000 software at six Air Force Logistics Command sites.

**Federal Aviation Administration –** The major proposal activity towards the end 1987 was a large project for the Federal Aviation Administration. The systems would be installed at nine regional engineering centers around the country. Intergraph already had three small installations at the FAA and the initial specifications were clearly written in their favor. The specifications called for minicomputers and workstations with dual screens, something that only Intergraph offered. After much arguing, these restrictions were loosened allowing Auto-trol to bid.

The FAA came to Denver in early 1988 for a fairly extensive benchmark test. Under Dave Peverley's direction the company was getting pretty good at these. The benchmark went very well and at the end, one of the FAA managers said, "I don't know if we want to select Auto-trol to be our vendor or just hire this guy Peverley." Indicative of how rapidly computer hardware prices were beginning to change, a decisions was made by Auto-trol to increase the memory in each of the proposed AGW/22s from 2MB to 4MB at no additional cost to the FAA. Apollo's prices had come down enough since the proposal had been submitted a year earlier that the company could do this without adversely impacting the profitability of the deal.

After several months of negotiations, Auto-trol finalized a contract with the FAA on October 3, 1988 for $16.6 million. The FAA eventually issued 20 contract modifications to this initial contract, the last one in September 1996 for a total of probably $30 million.

The next major step was to configure one of the regional engineering office systems and run through an extensive factory acceptance test. The acceptance test went well and by mid-February 1999 Auto-trol was ready to begin shipping equipment to the various FAA regional engineering offices. The contract called for nine regional systems totaling 22 servers and 176 workstations. Each initial configuration had six to ten Apollo workstations, digitizers, a plotter and a substantial amount of software and had a value of between $600,000 and $1 million. Throughout 1999 Auto-trol shipped one such configuration every 21 days like clockwork.

**Kennedy Space Center –** In late 1987 Auto-trol was awarded a substantial contract by Lockheed Aircraft. The Lockheed operation at the Kennedy Space Center in Florida was responsible for servicing the Space Shuttle between flights. Bill Brett had left Auto-trol several years earlier and gone to work for Lockheed which probably helped the company obtain this business. The contract involved a large number of AGW workstations and Series 5000 software to support this work.

**Los Angeles Department of Engineering –** An extensive effort was spent in 1989 on a proposal to the City of Los Angeles Department of Engineering. From a technical point of view, it was similar to the FAA project other than the fact that all of the installations were in one relatively small geographic area.

The competition with Intergraph was typical of what was going on between the two companies at the time. Intergraph was in the midst of making the transition from VAX-based systems to their new Clipper workstations but not all the company's AEC software had been ported. As a consequence, they bid a VAX-based solution with the intent to swap it out in the future for Clipper workstations. No one in the city's engineering department liked that option. Intergraph actually underbid Auto-trol $2.3 million to $2.6 million for Phase I of the contract. The third finalist, McDonnell-Douglas came in at $3.5 million. With options, the contract amounted to $6.4 million

One of the primary reasons for procuring this system was to support work being done on the huge Hyperion waste treatment facility that was then under construction south of Los Angeles Airport. An interesting sidelight was the fact that the city had a Computervision system that was being used to prepare detailed street and parcel maps of the city. This work was being done in a very laborious manner working from detailed survey data rather than scanning existing hard copy maps even though the city had an Optigraphics system it was very happy with.

### Auto-trol and the Navy's CAD-2 Program

*Note: See Chapter 14 on Intergraph for additional discussion of this government project.*

At the Defense Computer Graphics Conference in Washington, DC, in December 1985, Dale Christensen gave a briefing concerning a planned major Navy CAD procurement. Subsequently referred to as CAD-2, this project involved multiple procurements for different Navy commands using a basic set of common specifications. The impression in late 1985 was that the CAD-2 procurement would occur in 1986 or 1987 at the latest. In reality, this effort dragged out into the early 1990s before most of it was awarded to Intergraph. During the next five years, Auto-trol spent a large, but manageable, amount of effort tracking CAD-2 and preparing to bid for these very large contracts.

The Navy distributed a Request For Information (RFI) at a pre-bidders conference in White Oaks, MD in February 1986, but then nothing much happened. In 1987 the Navy distributed preliminary specifications and asked vendors to provide written comments. Potential vendors were also individually invited to meetings at the China Lake

 

Naval Weapon Station in California. Auto-trol took the position that the specifications were far too detailed and that the Navy should provide vendors with more opportunity to bid what they felt were the best approaches for getting the job done. Auto-trol also pushed to have more technical illustration functions included in the procurement which the Navy never did.

In early 1987 CAD-2 was restructured into five specific command-centric procurements:

- Ships - Naval Sea Systems Command (NAVSEA)
- Airplanes – Naval Air Systems Command (NAVAIR)
- Buildings – Naval Facilities Engineering Command (NAVFAC)
- Electronics – Space and Naval Warfare Systems Command (SPAWAR)
- Printing – Naval Supply Systems Command (NAVSUP)

The Navy planned to issue a single RFP document with each requirement identified as to its applicability to specific solicitations. In addition to criticizing overly detailed and restrictive specifications (which Auto-trol did every chance it had), the company recommended separate RFP documents for each of the five procurements. In March 1987, the Navy sent out an amendment to the RFI that added a huge number of complex requirements that were specific to ship design. Auto-trol took the position that these requirements went way beyond the capabilities of traditional CAD/CAM solutions and that implementing the tight software integration the Navy was looking for would be nearly impossible.

In April 1987, Christensen visited Auto-trol for a briefing that covered the company's WAPA installation, numerical control software, database software, industrial facility design and the latest Series 5000 capabilities. As described in Chapter 14, the procurement process then came to a grinding halt. By late 1988, Auto-trol was focused on two of the CAD-2 procurements, NAVFAC and NAVSEA.

Auto-trol was up against some fairly heavy competition. Several large defense contractors announced they were going to bid and talked about budgets in the millions of dollars to do so. As an example, Lockheed was teaming with Newport News Shipyard, Digital Equipment and McAuto. At this point, the company realized it was in over its head and pulled out of the CAD-2 procurement.

**Auto-trol becomes a reseller of Auto-CAD**

In early 1988, Auto-trol signed an agreement with Autodesk to resell AutoCAD as a complementary product to Series 5000. The company was starting to see some serious competition from AutoCAD but everyone at Auto-trol felt that Series 5000 was a far superior CAD package, which it was at the time. The concept was that when customers wanted copies of AutoCAD to complement their Auto-trol installations, it would be best if they bought the software from Auto-trol instead of a local dealer. This would help the company retain account control.

Except in Canada, Auto-trol never sold much AutoCAD. The company actually tried to sell the software at list price while most dealers severely discounted the package as a loss leader for other business such as selling the PCs AutoCAD ran on. The Canadian sales organization set up a separate group to pursue AutoCAD business while in the U. S. it was treated as just one more item in the price book.

 

**1990 – A year of major changes**

Every company goes through a number of inflection points where its business direction changes in sometimes unforeseen ways. Auto-trol went through such an inflection point in 1990.

- Jerry Sisson, who was vice president of sales and marketing, left the company in March 1990 and took a position with Precision Visuals in Boulder.
- Dave Hanna became vice president of marketing and initiated a thorough review of each market segment the company was in. The conclusion was to concentrate on the AEC sector and gradually withdraw from selling mechanical design and technical illustration systems.
- Howard Hillman took over running sales directly.
- In January, 1990 Auto-trol had another layoff and the company went into an aggressive cost containment mode including a 6% salary reduction.
- Hewlett-Packard's 1989 acquisition of Apollo made it more difficult, but not impossible, to negotiate special deals for computer hardware on large government procurements. Also, with their ME-10 and ME-30 packages, HP was now a competitor in some mechanical deals.
- Much of Auto-trol's software had been ported to Sun workstations and the company began to bid Sun hardware. Software development also shifted over to the Sun platform causing delays in a number of projects.

**Reselling Pro/ENGINEER**

In 1989, Auto-trol had signed an OEM agreement with Parametric Technology to resell Pro/ENGINEER. Series 7000 was strong when it came to mechanical drafting and NC but weak from a solids modeling point of view. Pro/ENGINEER was a strong solids modeler but initially had weak drafting and its NC capabilities were just about non-existent. The company's thoughts at the time were that it could sell customers a combination of the two packages and they would have the best of both worlds.

Auto-trol did not adequately take into consideration that most prospects would see this as a rather confusing approach and would prefer a single system that could do all three primary functions. Also, the company did not appreciate the fact that with a new system, PTC would be able to add new functionality at a pace far quicker than what Auto-trol was able to do with Series 7000. The result was that by mid-1990, Auto-trol was selling Pro/ENGINEER primarily as a stand-alone solution.

What Auto-trol had not taken into consideration was that PTC would actually end up being its primary competitor. In several situations, the company found itself bidding against PTC for the same business. In other cases, Auto-trol would do the hard work to get the prospect interested in the software and then PTC would declare the prospect to be a house account. They would pay Auto-trol a commission for the first sales but take all of the add-on business directly.

**Auto-trol struggles to find direction**

In late 1990, Auto-trol began experimenting with the idea of becoming more of a system integration business. A new Integration and Product Services Group (IPSG), managed by Terry Erdle, was established.

 

As it had for over a decade, Auto-trol was focused on three market segments:

**Electronic Publishing Systems (EPS) –** By 1991 Auto-trol was selling nearly $12 million annually in EPS systems including hardware, software and maintenance services. The company's flagship product in this area, Tech Illustrator PLUS, was the best package then available for high-end technical illustration and is still being sold by Auto-trol today. The problem was always that this was a small niche market and there were limited opportunities to expand the demand for high-end systems outside of the defense/aerospace and automotive industries. There were over 600 copies of Auto-trol's illustration software in use around the world in the early 1990s at companies such as Ford, General Motors, Pratt & Whitney and Boeing.

A major issue involving both the EPS and AEC efforts of the company was that both were dependent upon Series 5000 and there had not been a major release of this software since 1988. In the interim, much of the Series 5000 development resources had been consumed by efforts to port the software to Sun workstations and the implementation of an X-Windows graphics interface.

As an example of development interrelationships, a competitive shortcoming of Tech Illustrator was its inability to handle continuous tone scanned images. In order to add this capability to Tech Illustrator some fundamental enhancements to Series 5000 were needed. One reason for the lack of progress with Series 5000 was that the company had been working for over a year on a replacement to both Series 5000 and Series 7000 called Gemini. Auto-trol had difficulty defining what Gemini should be and the project was never adequately staffed.

While some of Auto-trol's data translators were quite good, others left much to be desired. The most awkward situation involved IGES which required a user to import the IGES file into Series 7000 and then translate the Series 7000 file into Series 5000 using a direct translator. Although it was possible to make most of these steps transparent to the user, if there was a problem it was nearly impossible to pin down where the error occurred.

In an attempt to increase the EPS market, Auto-trol began marketing a low cost version of its illustration software on top of a stripped down version of Series 5000. Unfortunately, it never did sell well. This was followed in 1991 by a new package called TI EXPRESS which sold for $10,000, about half the cost of TI PLUS.

**AEC Business Unit -** The AEC side of Auto-trol's story is more complicated. For the prior four or five years, the company had moved first in one direction then in another. Auto-trol had great plans for database-centric modeling solutions that could be used to design process plants and manage industrial facilities. The problem was that the company simply did not execute well in implementing these ideas. Some of the issues that had adversely impacted Auto-trol's ability to develop a suite of quality applications included:

- If the money and time invested in the MLC project described earlier had been spent internally on products such as VECTORPIPE the company would have been much further along in developing a quality process plant design solution.
- After the company acquired Tricad there was significant indecision about whether Tricad's G-3 or Series 5000 should be the CAD platform of the

 

future. This probably cost Auto-trol two releases of Series 5000. As an example, there was an effort to produce a control schematics package built on top of G-3 that never got off the ground. This probably cost the company a year in eventually producing a decent Intelligent P&ID package.

- For a number of years, Apollo workstations had been the company's primary development platform. When Auto-trol signed an OEM agreement with Sun Microsystems, the company implemented a massive switch to Sun workstations for software development. Most developers felt that it was a less efficient environment than what they had previously been using and the transition burned up a substantial amount of development resources.
- Porting Series 5000 and the AEC applications to the SUN platform and to ULTRIX, Digital's version of UNIX, had not been managed well. The development team was slow to appreciate the fact that software had to be implemented from the start with the intent that it would be as close to platform independent as possible.

The major problem was that Auto-trol was simply trying to do too many things at once. Nearly everything contributed to the company's bottom line to some extent so it was difficult to know what activities could be terminated or scaled back. For example, the company was seeing very little success in selling VECTORPIPE and other plant design software packages in the United States, but the same software was selling well in Germany and still does today. The same situation existed regarding its mapping software, GEOSTATION. It always sold well in Canada but never domestically.

**Mechanical Business Unit –** As mentioned earlier, the major marketing review initiated by Dave Hanna in 1990 had indicated that Auto-trol had little opportunity to become a major player in the mechanical CAD market. Supposedly, this was to result in the company reducing the resources devoted to Series 7000 and related products. Just the opposite happened however. In June 1991, Hillman hired Tom Rafferty as vice president of marketing and applications development, replacing Dick Burkley. Rafferty had previously been a vice president of development at Computervision and later at McDonnell Douglas. He came on board with the idea of developing a totally new CAD system from the ground up which would incorporate an internal database structured around the newly emerging STEP standard. This activity, initially called Monarch, took over the existing Gemini activity and charged off in a new direction.

### Trying to regain momentum

If there is one truism about the CAD industry it is that once a company's revenue starts slipping and earnings turn into losses, it is virtually impossible to turn the situation around. Auto-trol was no exception.

As a group, Auto-trol's management team spent considerable time discussing and planning the transition of the company to more of a system integrator and consulting firm. The company had shown with its large government contracts and several commercial accounts that there was a viable market for these services. The problem was how to get from point A to point B when the company was experiencing declining sales and incurring significant annual losses. Also, if Auto-trol was intent on making such a transition, why was it investing a considerable amount of money in Monarch?

Erdle was a good choice to head up IPSG, but he never had the resources needed to go out and sell integration services. It appears that, at the time, Hillman did not understand that selling professional services was significantly different than selling hardware and software products. In a consulting environment, the person who typically ends up as the project manager is usually the key person involved in the sales process. Auto-trol simply was not structured to operate in that manner.

Auto-trol was seeing considerable competitive pressure from Autodesk at this point but it was hard to get Hillman to respond. The previously mentioned agreement to resell AutoCAD had been cancelled by Autodesk in either late 1990 or early 1991. One meeting I participated in was indicative of the attitude. At a senior level sales meeting the conversation got around to competition and Ken Dedeluk, general manager of the company's Canadian subsidiary, mentioned the increased competition he was seeing from Autodesk in Canada. Hillman became very upset saying "If you are competing with AutoCAD, you are going after the wrong business." The misconception was that Auto-trol, and not the customer, could determine who the competition would be.

**Auto-trol in the 1990s and Beyond**

Auto-trol's revenues peaked in 1990 at $79.5 million although the company sustained a $1.3 million loss. In 1991, revenue slipped 19% to $64.4 million and earnings were a negative $7.9 million. This was the beginning of a long slide to where by 2001 the company was doing less than $8 million in annual revenues and still losing nearly $7 million a year.

Auto-trol Technology Revenue and Earnings

| Year | Revenue Millions | Earnings Millions | |
|---|---|---|---|
| 1976 | $7.00 | $0.50 | |
| 1977 | $12.50 | $1.60 | |
| 1978 | $21.90 | $1.80 | |
| 1979 | $33.50 | $3.40 | |
| 1980 | $50.80 | $3.80 | |
| 1981 | $46.30 | -$3.30 | |
| 1982 | $44.00 | -$7.60 | |
| 1983 | $54.10 | -$3.30 | |
| 1984 | $68.90 | $2.80 | |
| 1985 | $65.40 | -$11.70 | |
| 1986 | $62.30 | -$7.00 | |
| 1987 | $53.80 | $1.20 | 9 months[6] |
| 1988 | $78.20 | $2.10 | |

[6] In 1987 the company changed the end of its fiscal year from December 31st to September 30th. Therefore, the results for 1987 are for just nine months. Annualized, revenues that year would have been $71.7 million and earnings $1.6 million.

| | | |
|---|---|---|
| 1989 | $77.40 | -$2.40 |
| 1990 | $79.50 | -$1.30 |
| 1991 | $64.40 | -$7.90 |
| 1992 | $58.90 | -$9.10 |
| 1993 | $38.30 | -$10.50 |
| 1994 | $35.00 | -$6.70 |
| 1995 | $25.60 | -$10.80 |
| 1996 | $21.20 | -$11.80 |
| 1997 | $19.70 | -$7.80 |
| 1998 | $14.10 | -$6.80 |
| 1999 | $11.60 | -$6.90 |
| 2000 | $8.70 | -$6.30 |
| 2001 | $7.90 | -$6.50 |

Dave Hanna was killed in a tragic automobile accident in August 1992. To me, that took the heart out of the company. Howard continued to pour money into Monarch even after Tom Rafferty left the company. Interestingly, Bill Brett was hired back at that point and took over management of Monarch along with much of the rest of R&D.

Around 1993, Auto-trol linked up with a Houston, Texas-based software firm run by Susan Floyd. Floyd had developed a technical information management package while working for Lockheed at the Kennedy Space Center. Auto-trol eventually acquired the Houston operation and marketed the software as CENTRA 2000.

Another current product is KONFIG, a network management package derived from the TEAMS package mentioned earlier. In September 2002, Auto-trol changed the name of Centra 2000 to KONFIG Configuration Management. In fiscal 2001, the last year for which detail data is available, the company sold less than $2 million of software. The balance of Auto-trol's revenues came from maintenance services related to software and hardware sold in earlier years. Amazingly, the company was still spending nearly $6 million per year on R&D.

Throughout the 1990s, Hillman continued to loan the company money and then convert the loans into stock. By September 30, 2001 he owned 99.4% of the outstanding stock in the company and in early 2002 announced that the company was being taken private. The stock still owned by public shareholders was purchased for $0.20 per share. After a reverse 1:10 stock split several years earlier, that meant a share selling for the equivalent of $615 in 1980 was worth 0.03% of what it had been selling for 22 years earlier.

As this is being written in mid-2007, Auto-trol is still being run by Hillman. The company's primary software products continue to be the KONFIG configuration management software and Tech Illustrator. Auto-trol continues to sell GIS software, primarily in Canada, and process plant design software, primarily in Germany.

# Chapter 10

# Bentley Systems Incorporated

*Author's note: While in other chapters, individuals are typically referred to by their last names, in this chapter the five Bentley brothers are referred to by their first names. The term "Bentley" refers to the company, not an individual. I periodically acted as a consultant to Bentley Systems Incorporated from 1994 through 2003. Portions of this chapter are based on that personal experience.*

One of Intergraph's major customers in the early 1980s was DuPont's engineering department in Wilmington, Delaware. Keith Bentley had gone to work at DuPont after receiving a BS in electrical engineering from the University of Delaware and an MS from the University of Florida. DuPont was using its Intergraph systems for producing electrical diagrams for its process plants. Usage, however, was limited by the high per seat cost of adding more capacity.

Keith believed there was a lower cost alternative and set out on his own time to develop a software package called PseudoStation that enabled a user to access Intergraph's CAD software from a low-cost DEC VT-100 terminal equipped with a graphics card or a Tektronix storage tube terminal. PseudoStation proved to be particularly cost effective when DuPont designers wanted to simply make changes to existing drawings such as changing some text on a drawing.

In 1983, Keith left DuPont to work with his brother Barry in California at a company called Dynamic Solutions. Before leaving DuPont, Keith negotiated an agreement with the company under which he received marketing rights to the software in return for which he would provide technical support to the company's PseudoStation users. On the way to California, Keith stopped in Huntsville and offered the software to Intergraph. According to Keith, "I would have sold [PseudoStation] to Intergraph for $5,000, and that would have been that. [That I didn't] is one of a series of lucky coincidences….."[1] The software was first shown publicly at an Intergraph users meeting in Huntsville in 1983 after Keith joined Dynamic Solutions.

Los Angeles had a large number of Intergraph installations and soon Keith and Barry found a receptive audience for PseudoStation. Keith founded Bentley Systems Incorporated to continue development work on the software and arranged to have Dynamic Solutions market the package in exchange for work he did on the latter company's software. Actual sales of PseudoStation began in June 1984.

At this point, Keith became convinced that what Intergraph was doing on a VAX, he could do on a IBM PC/AT. This new version of the software was soon known as MicroStation and was shown on a Compaq 286 at an Intergraph users meeting in Orlando, Florida in the Spring of 1985.[2] Soon Keith and Barry sold their interest in Dynamic Solutions and relocated back to Pennsylvania, initially to Philadelphia, then Lionville and subsequently to Exton. By then they had sold 350 copies of the terminal-based PseudoStation. Scott Bentley joined BSI to handle the business end of the company and he was subsequently joined by a fourth brother, Ray Bentley.

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[1] Solomon, R. E., "Those fabulous Bentley Brothers, MicroStation's building blocks," *MicroStation Manager*, June 1992, Pg. 76
[2] *A-E-C Automation Newsletter*, August/September 1989, Pg.13

 

In January 1987 Intergraph purchased a 50 percent interest in Bentley Systems for $3 million and announced that MicroStation would be marketed on both UNIX and PC platforms. A four-person board of directors was established with Intergraph having two seats on the board and Keith and Barry Bentley having the other two. One problem with this arrangement was that each party owned exactly 50 percent of the business and had half the board seats. Many joint ventures split something like 49/51 so that there is a clear controlling interest. This would prove to be a problem for Bentley a few years later.

By mid-1989, there were multiple versions of MicroStation being sold:[3]

- MicroStation PC for DOS-based personal computers.
- MicroStation MAC for the Apple Macintosh II workstation.
- MicroStation 32 for UNIX workstations including those produced by Intergraph.
- MicroStation GIS, also for 32-bit Unix workstations.

An OS/2 version of MicroStation was also developed, primarily at the request of a Midwestern DOT. According to Keith the company spent more money on development with less return in revenue than on any other project. It is not clear if this DOT ever used the OS/2 version of the software.[4]

MicroStation's primary attractiveness for the Intergraph user community was its close mirroring of Intergraph's IGDS command structure. As stated by Dr. Joel Orr:

> "….If you are familiar with IGDS, you will feel completely at home with MicroStation. In fact, you will probably be amazed at the completeness of MicroStation's implementation of IGDS." Orr went on, however, to critique the software's user interface. "If you never worked with IGDS, Microstation's human interface takes some getting used to. The system is designed for production. You can sketch, design, play around with it, but its primary features are speed, power, and ease of use (contrasted with ease of learning)."[5]

At this point in time, numerous industry observers such as Ed Forrest believed that the Apple Macintosh was the machine of the future, especially for architects and engineers because of its user interface. According to Forrest:

> "MicroStation Mac software is a new, original, popularly-priced, high performer for the model-design-draft automation field. Nothing I know of at this point comes close. The software behaves as if the Macintosh was designed exclusively for it; while the Macintosh acts as if a software worthy of its capabilities as a 'humanized' engineering workstation is finally here."[6]

At the time, MS-DOS PC and UNIX workstation interfaces were keyboard intensive compared to the mouse-driven Macintosh. Porting MicroStation to the

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[3] *A-E-C Automation Newsletter*, August/September 1989, Pg.13
[4] Interview with Keith Bentley, June 29, 2006
[5] *A-E-C Automation Newsletter,* August/September 1989, Pg.19
[6] *A-E-C Automation Newsletter,* August/September 1989, Pg.20

 

Macintosh appeared to be a smart move at the time. This market never really took off, however, mainly because Apple never put adequate marketing and hardware development resources behind it. One potential problem for Bentley was the company's plan to install hardware locks for the Macintosh version of its software at a time when customers were reacting adversely to similar plans coming from other software vendors.

By the summer of 1989, 20,000 copies of MicroStation were in use. Its price at the time was $3,000, comparable to AutoCAD. MicroStation was subsequently ported to the HP 700 series of engineering workstations in early 1992 as well as other UNIX machines.

**Bentley takes on the appearance of a real company**

Once Intergraph began selling Bentley's MicroStation software in 1987, Bentley basically stayed in the background, focused on software development. The company spent little effort creating media awareness of Bentley as a business entity. This began to change in the summer of 1992. Shortly after that year's A/E/C SYSTEMS conference, Bentley invited representatives of most of the publications covering the CAD industry to the company's headquarters in Exton, Pennsylvania. Although some Intergraph executives were there, the event was fundamentally run by Bentley employees and managers.

The company was very open about its plans for future software products in spite of the fact that several editors for AutoCAD-centric publications were present. At the time, there was no indication that the tight relationship between Intergraph and Bentley would blow up within two years. Bentley executives led by Keith Bentley, made it clear, however, that AutoCAD was seen as the primary competitive product.

1992 also marked the point at which Bentley began to focus more intently on co-existing with AutoCAD. The company added the capability to MicroStation to directly import AutoCAD .dwg files using the Marcomp AutoDirect toolkit. Marcomp was a small software company that specialized in reverse engineering the .dwg file format. It was subsequently acquired by Visio in 1997. Called AutoCAD Access, it was packaged with several other MicroStation enhancements as a no-cost upgrade for existing MicroStation Release 4 users. Bentley and Intergraph referred to this upgrade as MicroStation Nexus.

Further indication that Bentley was increasingly focused on competing with Autodesk was the company's support of a book that targeted AutoCAD users who were making the transition to MicroStation. Titled *MicroStation for AutoCAD Users*, it was written by Frank Conforti and Ralph Grabowski. The next step occurred when Intergraph initiated a trade-in program for AutoCAD users. For $500 per license turned in customers would receive a copy of MicroStation, MicroStation Nexus and the book.

In 1992, Intergraph sold $79 million worth of MicroStation. Mid-1993 saw the launch of MicroStation Version 5. This release, priced at $3,790, involved a substantial amount of development effort that resulted in the following major enhancements:

- The porting of the software to Windows NT on Intel platforms with a support commitment for Intergraph's Windows NT implementation of NT on Clipper workstation that were expected later in 1993.
- The ability to write .dwg files as well as read them.

 

- User interface enhancements including the capability to group customization features in "workspace shells" for different users and applications.
- Hypertext-based on-line user documentation.
- Drafting enhancements including associative hatching and persistent geometric constraints.
- Composite vector and raster documents along with raster editing capabilities.
- New surface modeling features including expanded use of NURBS surfaces.
- Improved visualization tools including pattern mapping.

At this point in time, I felt that for the money, MicroStation was a better buy than the then current version of AutoCAD.[7]

**Bentley splits from Intergraph**

By 1992, Intergraph executives began to realize that the nature of its business was starting to change. Up until that point, MicroStation was a tool that helped Intergraph sell large integrated systems. Overall, this one software package made up only a moderate portion of the total dollar revenue of a typical system sale. Hardware, application software and services made up far more. Intergraph primarily saw its competition being other large systems vendors such as Computervision, IBM and EDS/Unigraphics.

The future for Intergraph, however, appeared to be more software focused as the handwriting was on the wall that hardware was going to be a smaller piece of the company's business – not immediately but probably within a few years. In that scenario, MicroStation would become a significantly larger piece of Intergraph's business but it only controlled 50 percent of Bentley. At that point, Intergraph approached the Bentleys about acquiring the portion of the company it did not own.

According to Keith, the amount Intergraph offered was far below what he felt the business was worth. His response was: "If that is all you think the company is worth, why not sell us your 50 percent interest at that price?"[8] Intergraph declined the counter offer and threatened to compete directly with Bentley with new technology it would develop, presumably its new Jupiter technology as described in Chapter 14. Bentley's counter was that if Intergraph offered a competitive product, then the exclusivity clause in the original marketing agreement would be null and void and that Bentley would market MicroStation independent of Intergraph.

Intergraph believed that it was in a commanding position since most MicroStation users were its customers and its sales force was in close contact with these organizations. In 1993 the differences between the two companies reached the point where they decided it would be best for each to go its separate way. Discussions over how best to do this continued for several months but by early 1994 it was no longer a secret within the industry that the two companies would be parting company.

Like most divorces, this one was not particularly pretty. The announcement was made at Intergraph's Spring 1994 user group meeting, IGUG. At earlier Intergraph user

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[7] *Engineering Automation Report*, August 1993, Pg. 3
[8] Interview with Keith Bentley, June 29, 2006

group meetings, Bentley personnel were frequently involved in presentations and demonstrations of new software. In 1994 the company was pointedly not represented. Instead, Bentley set up product demonstrations in a vacant shopping center a short distance away from IGUG that the company called "MicroStation Mall."

A number of software vendors who competed with Intergraph for applications business and hardware vendors joined Bentley at the mall. During his IGUG Keynote, Jim Meadlock, Intergraph's president and CEO, announced the new arrangement between the two companies. Meadlock pointed out that Intergraph would retain its 50 percent interest in Bentley except the company's board of directors would be expanded to five individuals and that Greg Bentley, who had recently joined Bentley, would join the board. That effectively gave the Bentley brothers control over the jointly owned company.

A key aspect of the agreement between the two companies called for Bentley to take over all marketing and sales responsibilities for MicroStation effective January 1,1995. Intergraph would continue to resell MicroStation and was expected to be the primary distribution channel for this software for the foreseeable future. Dealers would obtain MicroStation directly from Bentley and Intergraph applications from that company.

The expectation was that there would quickly be a growing number of MicroStation applications available from independent software firms. Although this did happen, it never took on the dimensions that it did at Autodesk. A major concern among users was the perceived lack of a single point of contact in the future. Intergraph countered by stating that it would continue to support all hardware and software it sold.

The excitement among Bentley personnel at IGUG was very high. They believed that on January 1, 1995, Bentley would be like a new startup, except one with 150,000 users, a quality product and a 110-person development and support organization.[9]

**Establishing a real software business**

For ten years Keith and his brothers only had to worry about developing software. Now they had to put together a real company in a matter of months that would take on sales, marketing and support of MicroStation. When Greg Bentley joined the company in 1994, he brought with him some valuable experience running a software company. Previously he had built Devon Systems into a successful vendor of financial analysis software for the investment community.

As head of distribution he set out to establish a value-added reseller (VAR) organization. To handle this task, Bentley hired Warren Winterbottom who had held the same position at Intergraph until about a year earlier. Within a year the company had signed up 135 VARs in North America as well as many in foreign countries. In addition to Winterbottom, Bentley hired a number of Intergraph employees who had been involved in the marketing and support of MicroStation while working for Intergraph including Jean-Baptise Monnier, Dick Fox and Brad Workman. Other new hires from other companies included Yoav Etiel (ISICAD), Peter Brooks (ANSYS) and Rebecca Ward (CADCentre).

Fairly quickly Bentley organized itself into three operating units:

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[9] *Engineering Automation Report*, June 1994, Pg. 2

 

- A development group under Keith that also included Barry and Ray as well as Steve Knipmeyer as vice president of software development. Interestingly, Etiel and his product marketing activity was placed within this group rather than the distribution organization.
- A distribution group under Greg with Winterbottom running North America and Fox responsible for Europe.
- An operations and services group under Scott.

Bentley set out to make its distribution organization different from Autodesk's. Whereas Autodesk had multiple dealers in a given geographic area competing with each other, Bentley intended to have fewer dealers who could focus on competing with the AutoCAD resellers rather than other MicroStation dealers. Also, there would no longer be restricted accounts. Bentley's dealers could compete directly with Intergraph's sales force wherever they wished.

With Autodesk clearly identified as the company's primary competitor (eventually Intergraph would be placed in the same category), Bentley set out to differentiate itself. While Autodesk prided itself in the number of third party software developers it had, Bentley made it clear that it planned to work with a limited number of strategic partners.

The company also began to emphasize the direct support of users. AutoCAD customers were required to contact their local reseller for support. Bentley, on the other hand, had established a Comprehensive Support Program (CSP) several years earlier and wanted its employees, even developers, to be in touch with users. Bentley was publicly on the record as stating that it planned to continue supporting multiple platforms including the Macintosh and a variety of UNIX platforms. Autodesk, meanwhile, was quickly becoming a Windows only vendor.

Software development was a two-prong affair. Some applications were being developed by strategic partners as described below while other programs were being developed in-house. The internally developed software included:

- **MicroStation Modeler –** a solids modeling package initially intended for mechanical design that was built on Spatial Technology's ACIS geometric kernel. Bentley had begun demonstrating this package in early 1994 and began shipping it, including thin shell parts and assembly management, in early 1995.
- **MicroStation PowerDraft –** a lower cost version of MicroStation intended for production drafting users who did not need all the design capabilities in MicroStation. PowerDraft, which began shipping in the spring of 1995, had a list price of $1,950. Bentley stated that it saw PowerDraft as competing directly with AutoCAD, not with AutoCAD LT. It included a BASIC user development capability for the development of customer applications.
- **MicroStation Review –** an easy-to-use package for redlining and revising MicroStation drawings. This package also sold for $1,950.
- **MicroStation Masterpiece –** a visualization package that incorporated ray tracing and radiosity tools. It was licensed from Spotlight Graphics, a company run by Peter Segal, which was subsequently acquired by Bentley. Masterpiece sold for $1,450.

Bentley also committed to maintaining support for MicroStation on Apple platforms with the announcement in early 1995 that a version of the software optimized for the Power Macintosh (using the Power microprocessor jointly developed with IBM and Motorola) would be available within a few months.

Within a year from the announcement that it was going separate ways from Intergraph, Bentley had grown to 275 employees, and 350 resellers worldwide and had nearly $100 million in annual revenues. The company claimed that over 500 independent software companies were developing MicroStation applications.

Internally, the focus was on implementing object-oriented technology. This was being done in two steps. The first was to add object technology to the MicroStation Development Language (in reality, much of MicroStation was written in MDL). This was initially called Objective MDL and subsequently renamed ProActiveM. The next step was to add object technology to MicroStation itself, resulting in Objective MicroStation. The terminology for this latter package was subsequently changed to ProActiveM VM where VM stood for Virtual Machine.

The original plan was to release a preliminary version of the object-oriented software to external developers later in 1995 and a user version in mid-1996. The programming effort turned out to be far more complex then originally contemplated and these products were subsequently replaced by MicroStation J as described below. Bentley also joined an industry initiative, the Design & Modeling Applications Council (DMAC), that was set up to work with Microsoft in adding three-dimensional extensions to Windows Object Linking and Embedding (OLE) technology.

It became somewhat clearer by mid-1995 that Intergraph's development of its new Jupiter technology as described in Chapter 14 was a significant contributing factor to the breakup between the two companies. This was partially because key Bentley individuals such as Keith had not been invited to participate in defining the new Intergraph technology. The conclusion they came to was that Intergraph was developing Jupiter in order to eliminate the need for MicroStation to support its applications. At Intergraph's IGUG meeting in Huntsville in May 1995, it was obvious that the split between the two companies was far from friendly. During his keynote address, Jim Meadlock included Bentley in a list of Intergraph competitors and there was virtually no mention of MicroStation during the talk.

Later that afternoon, Bentley invited IGUG attendees to hear its side of the story at an off-site meeting held on the University of Alabama campus. Greg Bentley, by now the company's chairman, laid out the issues that were driving the two companies farther and farther apart. The bottom line was that Bentley felt that Intergraph's focus on Jupiter would eventually eliminate the need for MicroStation. Since most of the current MicroStation based applications had been developed by Intergraph and would eventually be replaced by Jupiter applications, Bentley was faced with the task of either developing replacing applications itself or finding third party software firms interested in doing so. A few such applications were demonstrated at the 1995 IGUG meeting but it was obvious that Bentley had its work cut out. This friction between the two companies led to a number of lawsuits that would drag on for years.

At the same time, Bentley began to aggressively push its Comprehensive Support Program (CSP) which distinguished it from Autodesk. CSP provided software upgrades as part of the service, the same service that customers received from large turnkey vendors as part of their maintenance contracts. By April 1995, 20,000 MicroStation licenses out of a total of 170,000 were covered by CSP agreements. This number would escalate rapidly in coming years.

**Bentley's moves into the application arena**

Once Bentley established its independence from Intergraph, the company set out to become a vendor of a broad range of graphic and data management applications rather than just a vendor of basic CAD software. At the time, Autodesk was also making the same moves. Bentley took a two prong approach to establishing a position in the application area. On one hand, the company began building up its internal development staff while on the other hand, it established a number of "strategic relationships" with a group of independent software firms between 1994 and 1996.

**Jacobus Technology –** One of the first such strategic relationships was with Jacobus Technology of Gaithersburg, Maryland. Jacobus was a developer of process plant design and visualization software founded in 1991 by Alton (Buddy) Cleveland, Vern Francisco, Chet Tabaka and Jerry King, all of whom previously worked at Bechtel, the global engineering and construction company. While at Bechtel, primarily with the company's Power Division in Gaithersburg, they had developed a plant design package tailored to Bechtel's specific needs, 3DM, and a visualization package, Walkthru.

Cleveland, who would eventually become a senior executive at Bentley, graduated from John Hopkins University in 1972 with a degree in operations research. After several years developing engineering analysis software for Bechtel he was given the task of installing the first CAD system at Bechtel's Gaithersburg office in 1980 - an Intergraph IGDS system that used a DEC PDP 11/70 computer. 3DM was developed about the same time that Intergraph was working on its Plant Design System (PDS). The intent was to develop software that was more tailored to Bechtel's needs and was less complex than PDS. Walkthru followed a few years later. The significance of these developments was demonstrated by the fact that Cleveland was appointed a Bechtel Fellow, a fairly significant honor.

Like many other companies, Bechtel felt that it could generate some incremental revenue by selling internally developed software on the open market. Bechtel Software Incorporated was established to do this with 3DM and Walkthru but was never very successful and ended up just selling the software in special situations. When Bechtel decided not to fund further development of these packages, the individuals listed above established Jacobus.

The new company's product strategy was to use object-oriented software technology to create basic plant design technology it called JSpace and then to build task-specific applications around this core. Initially, the plan was to work with both Autodesk and Bentley. The company grew slowly over the next few years. An interference detection package that worked with both MicroStation and AutoCAD was released in mid-1992.

The initial core of JSpace was completed in 1993 and several applications were subsequently added including JT/ID for interference detection and JSpace Viewer for animation and visualization. These were followed by JSpace Vantage, a low cost model review and query package, and JSpace Vista which extended the Vantage package into more of an information delivery and decision support system. The company provided underlying technology to software vendors such as Rebis as well completed products to end-user organizations including Bechtel, DuPont and Rust Engineering.[10]

In late 1994 Bentley made a minority investment in Jacobus (approximately 25 percent) and the company became a "strategic affiliate." Supposedly, this was not intended to be an exclusive relationship but fairly soon it became such. By early 1997, Bentley had made additional investments in Jacobus and held a majority interest in the company. Rebecca Ward moved over from Bentley to Jacobus as vice president of strategic accounts.

**WorkPlace Systems –** This activity started off as a joint venture between Bentley and Primavera Systems. The intent was to offer life-cycle solutions for facility asset management using software from these two companies as well as technology and consulting services from a European company, Opti Inter-Consult, which was an earlier Bentley subsidiary. George Church, who had previously been with Intergraph, was president of WorkPlace Systems while Tuomo Parjanen, the former head of Opti Inter-Consult managed WorkPlace's European operations.

**GEOPAK –** The AEC software industry is full of examples where an architectural or engineering firm created software for their own use, recognized that it had general value and began to sell the software to other A&E firms. Few have been successful, primarily because they never realized that the software business is a lot different than running an A&E firm.

GEOPAK which was in North Miami Beach, Florida at the time was a clear exception. It was established in 1984 by Beiswenger, Hoch, and Associates to develop and market civil engineering software for Intergraph IGDS systems. One of the company's first software efforts was a program for calculating right-of-way geometry. The software was called GEOPAK for Geometry Package and the name stuck.

In 1990, it was set up as a separate company, but still sharing facilities with Beiswenger, Hoch, and Associates. The result of this close relationship was that a programmer working on a new GEOPAK software feature could simply walk down the hall and talk to several project engineers to get their opinion as to the best way of doing the particular task in question.

The company was run by Gabe Norona, whose father, Francisco Norona, was the president of Beiswenger, Hoch, and Associates. As MicroStation replaced IGDS as Intergraph's primary graphics systems, GEOPAK's focus shifted also. Norona realized that the PC would soon become the primary computer platform in the civil engineering market and began focusing GEOPAK's development efforts on that version of MicroStation. By 1995, GEOPAK was a serious alternative to Intergraph's InRoads civil engineering software and Bentley quickly struck a deal with Norona for GEOPAK to become a strategic affiliate.

The GEOPAK software covered a broad spectrum of civil engineering applications including digital terrain modeling, survey, roadway design, site design, bridge design, drainage, reinforced concrete design and construction management.[11]

**BRICS –** BRICS was a Belgium developer of architectural software that Bentley also acquired a minority interest in. BRICS had developed an architectural modeling package that formed the basis for Bentley's TriForma product. This relationship did not

[10] *A-E-C Automation Newsletter*, December 1994, Pg. 2
[11] *A-E-C Automation Newsletter*, August 1997, Pg. 6

pan out and Bentley eventually gave back its interest in the company in exchange for the source code to the architectural software. In the late 1990s Brics became a provider of Internet-based information management solutions in addition to its architectural software and changed its name to Bricsnet. It lasted for a few years before failing during the Dot Com bust.

**NetSpace Systems –** This was a wholly owned Bentley subsidiary located in Huntsville that was responsible for marketing mapping and asset management software to the utility and telecom industries.[12] It initially had about 30 employees and was headed by Andrew Coe. Early software products built on top of MicroStation GeoGgraphics included ESpace and GSpace for the electric and gas distribution industries.[13]

**Bentley's "Coming Out Party"**

At the A/E/C SYSTEMS '95 conference in Atlanta, Georgia, Bentley came across as a major player in the AEC CAD industry with a show presence comparable to that of Autodesk and Intergraph. In fact, company employees talked about this as being the company's "coming out party." Bentley garnered a substantial amount of attention with giveaways, a design competition and a 1995 Ford Probe door prize.

It turns out that up until this conference, Greg Bentley and Jim Meadlock had never actually met. Carl Howk, the publisher of *A-E-C Automation Newsletter* at the time, relates how he walk over to Greg at the Bentley booth and asked Greg to come with him. The two proceeded over to the Intergraph booth where Howk introduced the two and claims that they actually had an amicable chat.[14]

This conference was also marked by the announcement of a three-way deal between Bechtel, Jacobus and Bentley under which Jacobus acquired rights to previously mentioned 3DM and WalkThru packages developed by Bechtel. In turn, Bechtel received rights to future Jacobus software products and Bentley became the distribution channel for Jacobus software. Bechtel also agreed to standardize on MicroStation and to purchase $2 million of Bentley products over the next three years.[15]

**Bentley begins building a document management business**

By mid-1996, it was obvious that managing CAD data would eventually become nearly as important as creating it in the first place. Bentley's first step in this direction consisted of two packages. TeamMate operated as an integral part of MicroStation and was available to users whenever MicroStation was loaded. OfficeMate, on the other hand, was a standalone version of TeamMate that could access files on its own and could be used to manage non-MicroStation files as well as MicroStation files. An important characteristic of this software was that the programs were able to manage reference files including symbols and text fonts linked to the drawing files being viewed.

In a keynote address at A/E/C SYSTEMS '96, Keith emphasized the pending impact the Internet would have on the design community. During the keynote he

[12] *A-E-C Automation Newsletter*, December 1996, Pg.12

[13] While most software companies that offered geospatial packages referred to this market as GIS for Geographic Information Systems, Bentley tended to call it Geoengineering it that the company saw it as a blend of CAD, geographic and data management technologies.

[14] Personal conversation, January 2005

[15] *A-E-C Automation Newsletter*, June 1995, Pg.10

 

demonstrated the ability of MicroStation to access component data over the Internet, insert the data into a drawing file and then manipulate that data as if it had been created locally. The tool for doing this was called Engineering Links.[16]

Around this time there were the first rumblings that Intergraph wanted to divest itself of its share of Bentley. The company announced that it had retained an investment banker, Robinson-Humphrey of Atlanta, to establish a value for its interest in Bentley and possibly find a buyer. Nothing came of this effort. As described below, Bentley would eventually file for a public offering and then withdraw that filing due to unfavorable market conditions.

**The product line matures**

In the fall of 1996, Bentley began packaging combinations of Bentley and third-party software modules in industry specific bundles using the "Engineering Office" nomenclature. The first four of such bundles and their prices were GeoEngineering ($7,250), Mechanical ($5,995), Building Design ($5,995) and Plant ($7,995). The Mechanical Engineering Office included MicroStation Modeler, TeamMate, MasterPiece, SRAC's COSMOS/M PowerDesigner, MDI's ADAMS/MS Motion and Baystate Technologies DRAFT-PAK.

It was also around the same time that Bentley launched Bentley SELECT, a support and software subscription service that effectively replaced the previously described CSP program. One aspect of the SELECT program allowed customers to lease Bentley software for periods as short as three months. This was particularly attractive to architectural and engineering firms whose workloads fluctuated as new projects were initiated.[17]

In late 1996, the company held a symposium on ProActive Engineering in Orlando, Florida to which it invited senior managers from companies using MicroStation. Nearly 400 showed up. Discussions focused on issues such as increasing enterprise productivity rather than focusing on just personal productivity and how networking was no longer an ancillary function but was the key element around which systems of the future would be built. Bentley used the symposium to announce a suite of enterprise-oriented software products collectively referred to as the "Engineering Back Office." The centerpiece of this strategy was a new line of middleware programs called "ModelServer."

The implementation of the ModelServer strategy was predicated on a three tier software architecture. The presentation layer was the interactive software most visible to the user, the application layer was the software that manipulated design data and the storage layer consisted of the file and database programs that managed the data. The assumption was that changes could be made to software in one layer without having to modify software in the other layers.

Initially there were three ModelServer software products:

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[16] Around this time, Bentley's marketing department began generating a large number of conflicting names for various Bentley software products and services. As an example, one aspect of the previously mentioned Objective MicroStation was a tool called ProActiveM that enabled a component vendor to include programs for manipulating the company's component data. More than once I asked the company to produce a guide that would help analysts and writers keep these different names straight.

[17] *Engineering Automation Report*, October 1996, Pg. 12

 

**ModelServer Publisher –** This server-based software converted MicroStation and AutoCAD files to a Web-based format that could be viewed by standard Web browsers such as Netscape and Internet Explorer. The receiving computer did not need a copy of MicroStation or AutoCAD to view these images. Another key characteristic of this software was that the drawing images produced by ModelServer Publisher could not be modified by the person viewing them. There were two versions of this software – a single active user version that incorporated Netscape's FastTrack Server and sold for $9,995 and a multi-user version that incorporated Netscape's Enterprise Server and sold for $24,995.

**ModelServer Continuum –** MicroStation users could store both graphical and non-graphical information in a relational database and then extract applicable data to meet the needs of a specific work session. When the user was through making changes to the data, ModelServer Continuum would then update the database with the changed data. A typical application using this software was MicroStation GeoGraphics. Rather than developing this program entirely in-house, Bentley took advantage of Oracle's Spatial Data Option to provide some of the capabilities in Geographics. A beta test version began shipping in April 1997.

**ModelServer TeamMate –** The TeamMate product described earlier was a file based solution. ModelServer TeamMate was a server based implementation that supported both MicroStation and AutoCAD documents.

Bentley planned to publish Application Programming Interfaces (APIs) for each of the ModelServer applications in a specification known as Open Engineering Connectivity. [18]

**Bentley matures as a company**

By 1997, Bentley was doing $160 to $170 million in annual revenue with Intergraph representing just 13 percent of the company's sales.[19] At A/E/C SYSTEMS '97 in Philadelphia, Keith Bentley participated in a joint keynote address with Jim Meadlock, Intergraph's CEO, and Carol Bartz, Autodesk's CEO. The key Bentley announcement was that the company was working on a Java-enhanced version of MicroStation to be known as MicroStation J. The intent was to create object-oriented software that would be less platform dependent than existing packages were. In effect, a Java enabled version of MDL called JMDL was developed and MicroStation/J replaced the previously described work on Objective MicroStation (subsequently renamed ProActiveM VM).

A key part of the plan involved licensing the Java Virtual Machine source code from Sun Microsystems so that a Java virtual machine could be built directly in MicroStation. Bentley's new schedule was to have MicroStation/J and Java-based applications in the hands of users during the first quarter of 1998. Meanwhile the company continued to make incremental enhancements to the basic MicroStation program and a wide range of industry-specific applications.

Like most complex software projects, this one took longer than expected and Bentley eventually released MicroStaion/J in the latter part of 1998. Not only did this version of MicroStation incorporate Java technology, it also implemented the Parasolid

[18] *A-E-C Automation Newsletter*, December 1996, Pg.12
[19] *A-E-C Automation Newsletter*, October 1997, Pg. 4

 

solid geometry kernel. A significant difference between traditional Java applets and those written in JMDL was that the JMDL applets could work with persistent data. Java typically did not store objects on the client machine. Therefore, it was difficult to write Java programs that created and managed large models. By using JMDL, the data, as well as the procedures incorporated into an applet, became part of the design database. This database could then be stored locally or on a server, but, most importantly, it did not require access to the server from which the applet was originally obtained.

MicroStation/J also included raster editing capabilities from HMR (another company Bentley had invested in), the ability to obtain symbology over the Web and insert it into drawings and models, surfacing of three-dimensional models, improved item selection, the ability to produce three dimensional views with edges highlighted, improved photorealistic shading speed and a wide variety of data exchange routines. For $4,795 a customer not only received MicroStation itself but also one of five application packages the company called Engineering Configurations; TriForma, Modeler, GeoGraphics, CivilPAK or Schematics.

**New applications begin to flow**

Bentley seemed to shift into a higher gear towards the end of 1997 with new products being introduced at an accelerated pace. In December 1997, Bentley acquired the remainder of Jacobus which it did not already own and Jacobus became a wholly owned subsidiary. PlantSpace encompassed two groups of software products, programs that could be used to manage plant design software whether that design data was created with Jacobus software or not and programs for designing process plants. Most of this software was developed using the company's JSpace object-oriented software technology.

PlantSpace Enterprise Navigator converted plant design data from multiple sources into a common database that could then be displayed using a variety of viewing packages. Fairly powerful navigation tools were provided so that a user could view a section of the plant or a particular process line that ran throughout the plant. PlantSpace Interference Manager enabled users to perform interference detection even where the data was created by a variety of different design systems. Another package was called PlantSpace Schedule Simulator. It worked with project planning software such as Primavera's Project Planner and Microsoft's Project to visualize the actual construction sequence of a project. There were other PlantSpace software products based on JSpace that help user organization manage plant design information.

The PlantSpace design packages covered the full spectrum of plant design applications including a database-oriented P&ID product, piping design, pipe support design, equipment layout, structural, HVAC and electrical raceways. Most of these packages sold for $3,000 per copy or less. A complete plant design suite of software packages could be put together at a fairly reasonable cost. [20]

A new term began to be used by Bentley in the fall of 1997. At its second ProActive Engineering Symposium, this time held in Palm Springs, California, the company emphasized the "Bentley Continuum" to approximately 500 attendees. This was a far more comprehensive idea than the way the term was used in regards to the previously mentioned ModelServer Continuum. In effect, it described a cooperative

[20] *A-E-C Automation Newsletter*, February 1998, Pg. 6

working relationship between technology vendors and technology users that could potentially help these users stay ahead of their competitors. This symposium was followed up a few months later by a similar meeting in Rome, Italy.

About the same time, Bentley announced that it was replacing the ACIS geometric kernel in MicroStation Modeler with Parasolid from EDS due to performance and functional shortcomings with ACIS. The plan was to add Parasolid capabilities to MicroStation itself, not just to the Modeler product.

In late 1997, Bentley announced a new SELECT release of MicroStation called MicroStation SE. It incorporated digital signatures, photorealistic rendering, raster image viewing and other capabilities that previously were extra cost options. MicroStation SE was only available to SELECT clients and new customers. If existing users wanted this upgrade they had to sign up as SELECT customers.

Bentley also added a new strategic affiliate, HMR. This company was a developer of raster editing software including a program called Descartes. HMR's Image Manager software was a component of the newly released MicroStation SE software.[21] The HMR software fit in well with Bentley's efforts to expand its presence in the mapping market. At this time, Jean-Baptise Monnier was vice president of geoengineering products at Bentley. The company initiated a series of annual symposiums covering its mapping technology at the Keystone Resort in Colorado.

One of the major problems facing users of this technology at the time was the lack of top management support among user organizations. I was a speaker at one of these symposiums and remember asking the attendees "How many of your top executives understand what it is you are trying to do?" and having just one hand in an audience of several hundred go up. The Bentley's credit, over the next several years the company invested heavily in trying to get the message out to the executive management of the companies it served.

In the area of architectural design, the company's new flagship product was MicroStation TriForma, a three-dimensional building modeling application first introduced in April 1996. By mid-1998, this software was in its third release, incorporated the Parasolid geometric kernel and was slowly gaining acceptance among architects around the world. Architects, in general, were having a more difficult time moving from drawing-centric design to model-centric design than were their mechanical engineering counterparts. Brad Workman, was Bentley's vice president of building engineering products at the time.

The GEOPAK portion of the company's product line was also maturing rapidly Of the 45 state highway departments using MicroStation in the spring of 1999, 15 were also using GEOPAK as compared to 21 who were using Intergraph's InRoads software. GEOPAK was increasingly being used to design complex facilities such as the highway interchange shown in Figure 10.1.[22]

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[21] *A-E-C Automation Newsletter*, December 1997, Pg. 14

[22] *A-E-C Automation Newsletter*, May 1999, Pg. 6

 

Figure 10.1

Palm Beach International Airport Interchange designed by Belswenger, Hoch & Associates using GEOPAK

**A new concept in data management**

ProjectBank, announced in late 1998, was a new Bentley technology initiative that was intended to enable multiple individuals to work on the same engineering model, record the history of all changes made to these models and even enable a project to integrate MicroStation and AutoCAD models in a single database. At the company's Proactive Engineering Symposium in Philadelphia that year, Keith Bentley spent nearly his entire 90 minute keynote describing how ProjectBank worked and its benefits.

Most of the then current design packages allowed collaboration at a file level, where individual components or information within each file could be used by just one individual at a time. Other users were effectively "locked out" from making changes to the model until it was released by the first user. Although there were some products on the market that informed other project participants when a file relevant to their work was changed, there were few tools that allowed collaboration at a component level within a file or set of files and enforced synchronization of changes to these components.

One of the underlying technical problems was that design data was typically stored in files and most software was set up to work with entire files. When one person checked out a file for modification, all other users were locked out until the file was checked back in. With ProjectBank, several users were able to simultaneously work on the same files at the same time. The software warned them whenever their individual work interfered with what someone else was doing. A key aspect of this software was its ability to create a list of all actions made on a design project. It tracked information associated with each transaction including the user name, the date and time, a description of the change and exactly what the change was. If a project manager was trying to understand why a change was made, it was possible to unwind the project back to a particular point in time. It was much like having a web browser forward and back button on the design software.[23]

ProjectBank Server was the server-level software that controlled access to a ProjectBank. One of the key characteristics of this software, which differentiated it from more traditional relational databases, was that the ProjectBank Server tracked the changes that were made to each component, who made them, and what other components were affected by these changes. Changes were basically tracked as individual "transactions."

Using a transaction-oriented project management methodology provided a number of advantages including rolling back a design to an earlier stage, marking project milestones and archiving the design at particular points in time. Since these transactions were stored at the component level, users could go back and review all of the changes that were made to a particular part in a mechanical assembly or a manufacturing cell on a factory floor, who made them, and, hopefully, why the changes were made.

ProjectBank was expected to go into beta testing in early 1999 and to be available as a released product later that year. It was not intended to be a separate product but rather, an extension of MicroStation/J. As with most complex software projects, things did not move as fast as expected nor did customers accept this new concept as quickly as Bentley had hoped. The software was finally released in March 2000 except that it only supported MicroStation. AutoCAD support was still off in the future. The changes Autodesk made to file structures in AutoCAD 2000 did not help the situation. *A-E-C Automation Newsletter* commented on the difficulty Autodesk and Bentley were having working with each other's data:

> "That brings us to an interesting subject. Would it be beneficial for Autodesk and Bentley to cooperate on exchanging internal AutoCAD and MicroStation file formats rather than treating them as confidential intellectual property? Granted, the two companies are fierce competitors, but they both spend considerable effort reverse engineering each other's data. If this manpower could be put to work on creating new applications solutions, it would benefit both companies and the user community, many of whom use both packages." [24]

ProjectBank as a stand-alone product eventually was incorporated into MicroStation and was subsequently known as "Design History."

### Transportation management

In mid-1997, Bentley purchased the specific portions of Graphic Data Systems Corporation (GDS) that were associated with intelligent transportation systems from Convergent Group. See Chapter 19. Together with GEOPAK, Bentley established a new affiliate called GEOPAK Transportation Management Systems Inc. (GEOPAK-TMS).

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[23] *A-E-C Automation Newsletter*, July 1999, Pg. 3
[24] *A-E-C Automation Newsletter*, April 2000, Pg. 4

The president of this new company was Ray Pittman who had been associated with GDS since the early 1980s when it was a McDonnell-Douglas product.

Initially, Bentley envisioned pursuing a broad range of intelligent transportation activities including real-time roadway and traffic monitoring, analysis, display and permitting/routing as well as inventory management. In succeeding years, the company's efforts increasingly focused on the routing and permitting of oversize and overweight vehicles.[25]

**Bringing the strategic affiliates in-house**

By early 1999, Bentley had grown to over 900 employees and had over 300,000 copies of MicroStation in use worldwide. Equally impressive was the fact that two-thirds of these users were covered by SELECT agreements. After an infusion of outside cash in Bentley, Intergraph, which by now represented only five percent of Bentley's revenue stream, owned just 40 percent of the company. With six or seven different Strategic Selling teams and a number of strategic affiliates, management of the company was starting to become unwieldy. Bentley reorganized its internal operations into two basic activities, Model Engineering and Geoengineering and brought several of the previously mentioned affiliates in-house.

Model Engineering incorporated the company's TriForma, PlantSpace and MicroStation Modeler products. As part of this move, the company's Jacobus affiliate was incorporated into the Bentley organization and Buddy Cleveland, the president of Jacobus, became a senior vice president at Bentley in charge of the Model Engineering business unit. This restructuring also resulted in the de-emphasizing the company's earlier interest on the mechanical design market. Modeler was repositioned as software to be used in conjunction with plant and manufacturing facility design. Bentley not only provided the software for designing a process plant but also provided the software needed to design specialized equipment.

Geoengineering continued under senior vice president Jean-Baptise Monnier but now also included former affiliates NetSpace and GEOPAK Transportation. Workplace Systems remained an independent unit as did two partially owned affiliates, HMR and GEOPAK. Corporate marketing continued to be the responsibility of Yoav Etiel.

**ProjectWise - A new generation of information management tools**

Tracking Bentley's nomenclature for its information management products can try a man's soul. As described above, Bentley introduced its initial version of TeamMate, a client-server approach to document management, in 1996. This software formed the basis of ActiveAsset Manager, a three-tier product, introduced in 1997 by the company's strategic affiliate, WorkPlace Systems. This in turn led to Bentley's introduction of its ModelServer family of project engineering IT tools which formed the basis for ProjectWise.

In January 1998, Bentley introduced ProjectWise, a pre-configured engineering information management solution which enabled users to quick start the implementation of data management software. Then, in June 1999, the company launched ProjectWise Release 2.2, a more robust version of the software together with an enhanced set of deployment services. In addition, Bentley announced that advanced ProjectBank features

[25] *A-E-C Automation Newsletter*, August 1997, Pg. 8

 

including the ability to "version" and "difference" different designs, the AutoCAD schema, support for cascading ProjectBanks, and access control would all be delivered via ProjectWise.

ProjectWise managed MicroStation files, files created with MicroStation applications such as TriForma and GeoGraphics, AutoCAD files, Microsoft Office files (Word, Excel and PowerPoint), and other corporate information. These documents were stored in their native formats in a central server or on distributed servers. Users did not need to know where a particular document was stored since the system understood how to find it. When an architectural or engineering design file was accessed, the system also knew which reference documents were attached to that file and accessed those documents as well.

ProjectWise initially came in two flavors: Extranet which enabled team members around the globe to access secure project data and WorkGroup which was designed for project teams where all the individuals were part of a single organization. The major difference was that the WorkGroup version was not Web enabled to the extent that the Extranet version was. Surprisingly, Bentley chose to use Sybase database management software to support ProjectWise. Prices started at $19,500 for the WorkGroup version and $50,000 for the Extranet version.

It should be pointed out that during 1999 and 2000, there was a tremendous amount of interest in developing Internet based solutions for managing AEC project data. Companies sprang up left and right and venture capitalists invested over $500 million in startups such as BidCOM, Blueline Online, BricsNet, Framework Technologies and Cubus.

**Bentley rebuilds relationship with Intergraph**

Since 1994, the business relationship between Bentley and Intergraph seemed to be little more than an armed truce. The sniping and legal disputes were usually kept behind closed doors but occasionally it would spill out into the open. It appeared that the relationship might be improving when, in May 2000, Bentley acquired Intergraph's InRoads civil engineering software along with related applications, InterPlot and Digital Print Room and the I/RAS raster editing applications.

Bentley paid Intergraph $35.4million for this software, $14 million up front and the balance over time. There were approximately 100 Intergraph employees involved in developing and supporting these applications, a number of whom were subsequently hired by Bentley. The agreement also called for Intergraph to continue acquiring MicroStation/J and related applications from Bentley for resale to its customers.

With InRoads, InRail, and a variety of related surveying applications together with GEOPAK, Bentley now controlled most of the large scale civil engineering market in the United States and a significant portion internationally where Infrasoft (see below) was a major competitor. During the previous several years, Intergraph had made a number of its applications CAD system neutral. In particular, InRoads' users could work with AutoCAD as easily as they could work with MicroStation. Bentley's management assured customers that the company planed to continue the marketing and support AutoCAD-compatible applications. Seven years later that is still the case although AutoCAD support tends to be several releases behind. There was some concern that

Bentley had taken this step because of a falling out with its strategic affiliate, GEOPAK. The company went out of its way to assure the media that this was not the case.

The Intergraph networked plot server products covered by the agreement included InterPlot and Digital Print Room. Bentley believed that in the growing engineering/construction/operations (E/C/O) e-business arena, the information integration role served by digital drawing dissemination would become an increasingly important factor. The Intergraph raster conversion products also fit into Bentley's new e-commerce strategy as described in the next section. The software facilitated the creation of digital "CAD" representations of existing hardcopy engineering drawings. The acquired products included I/RAS B and I/RAS Engineer, both of which had significant market share. This software was originally developed by Intergraph's ANA Tech subsidiary.[26]

**Viecon – A full court press on project extranets**

By mid-2000, Bentley seemed to be doing very well. The company's software was being used for everything from major airports to Olympic stadiums to nuclear power plants to 100-story office towers. Bentley's software was used by 18 of the 20 largest transportation design firms, 16 of the 20 largest process and petrochemical design firms, 12 of the 20 largest building design firms and 19 of the top 20 power plant design firms. In addition, many utilities, process and petrochemical firms and large manufacturing companies used Bentley's software as their in-house standard for engineering, construction and operation activity. In the transportation field, 47 of the 50 state Departments of Transportation used MicroStation.

This focus on large user organizations, a number of whom had over 1,500 MicroStation licenses installed, led Bentley to adopt business and product development procedures that specifically targeted large organizations. Autodesk had sold more copies of AutoCAD than Bentley had of MicroStation but the typical organization using AutoCAD tended to be smaller than Bentley's customers.

Bentley was continuing to put substantial development resources behind ProjectBank. This Java-based technology was intended to enable architectural and engineering organizations to manage design data at the component level. The effort was expected to eventually lead to a new design paradigm which was frequently referred to by Bentley personnel as "Engineering Component Modeling" or ECM. The use of ProjectBank to manage design at the component level went beyond the support of just MicroStation. Bentley was a strong proponent of an industry initiative called aecXML would eventually enable ProjectBank technology to work with design data irrespective of the tools used to create the data.

Meanwhile, the entire AEC industry was chasing a dream called "project extranets" as described above. There were two primary reasons for this interest – first, designers were creating massive amounts for project data that no longer could be managed just with an operating system's file management tools and, second, distributed project teams were becoming a common practice. Large petrochemical companies were starting to ask how they could effectively manage terabytes of project information.

At this time there were over 100 firms offering some form of Internet service to the AEC market. Some of the VC-funded extranets were starting to tout user success stories involving managing thousands of documents created by tens of firms with

[26] *A-E-C Automation Newsletter*, June 2000, Pg. 1

 

hundreds of registered users. The impact these companies were having on the AEC market was clearly shown at A/E/C SYSTEMS 2000 in Washington in June 2000 where nearly the entire show was dominated by extranet companies with neither Autodesk not Intergraph present with CAD-related demonstrations.

There were two types of project extranets being used in mid-2000. One involved self-hosted extranets where a design firm, contractor or owner/operator managed the computer hardware and software used to support the extranet. The other approach was to use a Web hosting service that specialized in construction industry-related activity to host and support the extranet. The companies engaged in this latter approach were referred to as Application Service Providers or ASPs. An ASP provided both access to the software and data storage facilities.

Self-hosted extranets utilized applications which were purchased from a software vendor while the Web hosting services usually charged fees based on the number of projects being managed and/or the number of individual users. In general, the self-hosted solution typically was most applicable to large organizations working on multiple projects while the hosting services enabled smaller firms to economically utilize the technology.

Bentley set out to provide both levels of technology and service. The company planned to offer a series of Web-based services under the name *Viecon* (pronounced "*v-con*"). As initially conceived, *Viecon* consisted of three major initiatives:

1. *Viecon.com*, an ASP service for document management and project collaboration,
2. *Viecon Licensing* which provided for the licensing of Bentley software on a by-person, by-project and by-month basis, and
3. *Viecon Platforms*, a local version of the software that would enable E/C/O companies to create their own in-house extranets.


Figure 10.2
Typical Viecon.com screen image

 

At first, Bentley planned to provide Viecon.com to its SELECT subscribers at no additional charge. The company began to invest in the computer resources needed to provide this service. The Platforms version was expected to be available by late 2000. What was not particularly clear was how Viecon was different from the existing ProjectWise product and why the company simply did not make ProjectWise more Internet compliant. Bentley also worked out a deal to provide Viecon technology to the American Institute of Architects' AECdirect service which never got off the ground.

**Users cheer MicroStation V8**

In 1998, the ProActive Engineering Symposiums morphed into a more traditional user conference. Over 2,500 users, resellers, development partners and Bentley employees attended the third annual Bentley International User Conference (BIUC) in Philadelphia September 17-21, 2000. The company used the conference to announce a major management restructuring. Keith Bentley, who had been the company's CEO since it was formed in the mid-1980s, relinquished that title to his brother Gregg. With Gregg the CEO, Keith assumed the title of Chief Technology Officer.

In reality, this is how the company had been functioning in recent years. Another significant change was that the company was reorganized into three divisions - operations under Malcolm Walter (who also became the company's COO), software under Buddy Cleveland and The Viecon Network under George Church. At the same time, Yoav Etiel, who had been Bentley's vice president of marketing since the mid-1990s, left Bentley and joined Bricsnet as Executive VP of Worldwide Marketing.

The highlight of the conference was the unveiling of MicroStation Version 8 which incorporated numerous long-desired enhancements and was scheduled for release around mid-2001. Bentley had been promoting the concept of gradual software evolution for the prior several years. The downside of this approach was that it inhibited radical change. MicroStation had the same basic data structure in 2000 that it had in the early 1980s, when it was based on Intergraph's IGDS. MicroStation simply had not been keeping up with the day-to-day needs of users.

Some of the significant enhancements incorporated into V8 were:

- Expanded coordinate storage from 48-bit integer to 64-bit floating point.
- Expanded the number of levels per file from 63 to virtually unlimited.
- Expanded the maximum file size from 32MB to 4GB.
- Expanded the maximum size of an individual element from 768 words to 64K words.
- Expanded the maximum cell (block) size from 64KB to virtually unlimited and dropped the then current six-character limit on cell names.
- Allowed an unlimited number of reference files.
- Expanded the number of vertices in a string from 101 to 5,000.
- Added Spatial's deformable surface modeler to MicroStation's Parasolid core.
- Added dynamic hatching and patterning.
- Utilized TrueType text fonts.

On top of these changes, MicroStation V8 was intended to work with both DGN (MicroStation) and DWG (AutoCAD) files. A user could read an AutoCAD file, make changes to it using MicroStation commands and then save it as either a MicroStation or

AutoCAD file. Likewise, a MicroStation drawing could be saved as an AutoCAD file. This was a level of interoperability that the CAD industry has not seen previously.

There were literally dozens of additional enhancements planned for V8, many of which brought cheers from a standing-room-only BIUC crowd at an evening presentation.[27] Few present that evening realized that it would be 13 months before V8 was officially released to the user community. During that time, MicroStation V8 changed somewhat from what was described at BIUC or perhaps these new capabilities simply were not discussed at that meeting.

The released V8 demonstrated a deep commitment to Microsoft technology. Support for UNIX and Apple versions of MicroStation was history as was Bentley's use of Java. While V8 still supported applications written in C, C++, and Java, the company dropped Java as a development language in favor of VBA (Visual Basic for Applications) and C#. V8 also represented a change in how the company provided ProjectBank-like technology.

Up to this point ProjectBank had only been used by a small number of MicroStation customers, mainly because it required the use of a special application server and stored its data in a format foreign to MicroStation. To access the special set of files stored on the ProjectBank server, users had to go through client-side ProjectBank software installed on their MicroStation workstations. ProjectBank had to maintain two sets of data, one on the server and one on the local client. Analyzing the differences between the two before changes could be submitted to the server was a time consuming process.

The new V8 file structure enabled the design history to be integrated directly into the design file. This eliminated the redundant set of data required by ProjectBank. Although MicroStation users could simply save their changes, V8 also provided a ProjectBank-like Commit function that created a special folder within the design file. After that, when the user performed another Commit, MicroStation recorded a copy of all the elements that had changed since the prior Commit. In addition to recording what had changed, who changed it, and when it was changed, users could also enter a short textual note to record why something was changed. This addition to the DGN file format enabled a transaction-based approach, preserving the complete history of each CAD file, so it could be "rolled back" to any point in its creation sequence.[28]

## Changing the business model

The launch of MicroStation V8 also represented some changes in Bentley's organizational structure and business practices. By late 2001, Bentley was a $200 million per year company that was growing about 15 percent annually. It was the second largest privately owned software company according to some sources.

Based upon this growth Bentley realigned its software teams into two groups: Create, led by Brad Workman, VP of Engineering Information Creation; and Manage and Publish, led by Bhupinder Singh, VP of Development. They both reported to Buddy Cleveland. On the Create side, MicroStation and its related portfolio of design tools were client applications focused on the user. Viecon, Bentley's project-specific website or

[27] *Engineering Automation Report*, October 2000, Pg. 2

[28] *Engineering Automation Report*, November 2001, Pg. 1

Extranet, was the hosted service for the Manage portion of the equation. And ProjectWise continued as Bentley's server-side solution for Publishing.

In a separate move that made Bentley the leading supplier of civil engineering software solutions worldwide, the company announced in October 2001 the completion of its merger with GEOPAK Corporation. Prior to the merger, Bentley had distributed GEOPAK products worldwide and owned a 25% stake in the company. Gabriel Norona, president and CEO of GEOPAK, became Bentley's senior vice president, Civil, and in this role took on the responsibility for the civil software Bentley had acquired from Intergraph including InRoads.

With V8, Bentley offered its customers three ways to acquire software:

- Traditional fully paid-up licenses with or without maintenance support (SELECT).
- Subscription-based licensing of MicroStation or other Bentley applications (includes SELECT). Subscription licensing was approximately 1/18$^{th}$ of the cost of the fully paid-up license fee per month.
- Subscription-based licensing of Portfolios—entire suites of Bentley software for a vertical market. At the time, there were portfolios for Building, Plant, Civil, and Municipal. [29]

**Bentley as a mature company**

By now, Bentley was becoming a reasonably mature business enterprise. The 2001 fall BIUC was postponed due to the events of September 11$^{th}$ and was rescheduled for late May, 2002 in Atlantic City, New Jersey. It drew keynote speeches from Rudy Guliani, the former mayor of New York and Walker Lee Evey, the program manager for the rebuilding of the Pentagon.

In late April 2002, Bentley filed a registration statement known as an S-1 with the U.S. Securities and Exchange Commission for its long-awaited initial public offering or IPO. Two significant pieces of information were missing from the document as filed – the total number of shares that would be outstanding after the IPO and what the initial stock price would be.

The Bentley S-1 was a large document, over 150 pages in length along with numerous accompanying appendices. The size reflected the then current skepticism concerning corporate financing and the SEC's attempt to ensure that potential investors had all relevant information before purchasing shares in a company. By comparison, when Autodesk went public in 1985, its prospectus was 38 pages, while Auto-trol Technology's in 1979 was 44 pages. Bentley's S-1 was complicated by the need to discuss in depth financial issues involving the company and Intergraph, GEOPAK, HMR and Rebis.

A careful reading of the S-1 revealed:

- Bentley's revenue had edged up from \$157 million in 1997 to \$203 million in 2001, representing slow but fairly steady growth. The company had been moderately profitable, losing money in 1998 and 2002 but making money in 1997, 1999 and 2001.

[29] *Engineering Automation Report*, November 2001, Pg. 1

- While some people thought that Bentley was simply making an investment in Rebis when they purchased an interest in that process design software company, it was now clear that Bentley intended to acquire Rebis. In January 2002 Bentley purchased 12.5% of Rebis for $5 million, placing a value of $40 million on the company. Upon completing the IPO, Bentley planned to purchase the balance of Rebis.
- The complex historical relationship between Bentley and Intergraph was spelled out in detail in the S-1. Ten years earlier, Intergraph was totally responsible for the marketing and sales of MicroStation. By mid-2002, only about 2 percent of Bentley's revenue was channeled through Intergraph.
- In March 1996, Bentley initiated an arbitration proceeding against Intergraph related to royalties it was due between 1987 and 1994. In March 1999, that disagreement was settled with Intergraph paying Bentley $27.4 million in cash and stock. This settlement also had the effect of reducing Intergraph's ownership of Bentley to 33 percent.
- The prospectus made it very clear that Bentley was in the midst of making two major changes to its business model. The most significant was the shift from selling fully paid up licenses to a subscription model with a wide variety of options for customers. In 2001, subscriptions paid on a monthly, annual, or longer basis amounted to 67% of Bentley's revenue. The other key change was a switch from nearly total dependency on resellers to a new distribution model in which Bentley's own sales force dealt directly with many major customers.

Overall, Bentley came across in the prospectus as a well managed company with significant products and customers – a far different situation than what investors had seen a few years earlier during the dot com boom and bust. The company's financial situation was in fairly good shape although it was apparent that Bentley needed an infusion of cash in order to continue to grow through acquisitions.

Market conditions didn't appear favorable for a technology-oriented IPO so on September, 16, 2002, Bentley initiated the required steps to withdraw its registration statement. According to Greg Bentley:

> "In the face of a market that has now apparently turned outright hostile to software company IPO's, Bentley has decided to remove the distractions and restrictions that accompany the IPO process and focus instead on managing our business which continues its growth and profitability. Bentley management remains confident in the Company's prospects and plans to reconsider the IPO when appropriate market conditions eventually return."

As of 2007, no IPO has yet occurred, primarily because the company does not appear to need an infusion of cash at this time. Unlike most private companies, Bentley publishes an annual report on its web site, although without profit details. In 2006, the company had revenues of $389 million, and between 2005 and 2006 spent over $200 on product development and acquisitions. At this point, Bentley had over 2,500 employees focused on four primary market segments, architectural design, process plant design, civil engineering and geospatial.[30]

**Infrasoft – The third leg of Bentley's civil product line**

Since Bentley acquired Infrasoft in 2003, this probably a good place to describe that company and its predecessor, MOSS Systems, Ltd. This story started in the United Kingdom in 1973, when three county councils in southern England decided to develop their own highway design software. These councils are much like the state DOTs in the United States. At the time there was little software available for roadway design, particularly software developed to meet UK standards.

The first release of the group's design software occurred in 1975. Like most other engineering solutions in those days, the package, known as MOSS, was batch oriented and ran on both mainframes and large minicomputers. In 1983, five of the original developers left their government jobs and formed MOSS Systems, Ltd. to develop and market the software to government agencies and private engineering firms. Within a few years, 49 out of the 50 county councils in the UK were using MOSS.

MOSS Systems' international sales activity was initially concentrated in other English speaking countries. The company entered the U.S. market in the late 1980s, signing distribution agreements with McDonnell Douglas and Auto-trol Technology[31]. McDonnell Douglas sold Prime and Digital minicomputer versions of the software while Auto-trol sold Apollo (later Hewlett-Packard) and Sun versions. The Auto-trol activity spurred Moss Systems to create an interactive implementation of the software with a graphical user interface. By the early 1990s, Auto-trol had taken over all of the North American distribution activity, but new sales were few and far between. Elsewhere around the globe, MOSS Systems was doing far better, with sales activities in over 50 countries.

Richard Fiery was one of the application engineers supporting MOSS at Auto-trol in the early 1990s. As a registered PE with a BS and MS in civil engineering from the University of Virginia, Fiery decided to go back to school and work on an MBA. At the University of Pennsylvania's Wharton School of Business, one of his class projects was to put together a business plan for a new enterprise. Part of the project involved writing a private placement memorandum for the venture. Fiery's plan was for a business enterprise that would take over the distribution of MOSS in North America. This was to be Infrasoft. Fiery won an award for the best business plan submitted along with a $50,000 grant to get it started.

His first step was to convince MOSS Systems and Auto-trol to allow Infrasoft to take over the sales and support of MOSS. This was apparently relatively easy to do since Auto-trol was de-emphasizing its AEC activity and MOSS Systems wanted to jump start its business in this part of the world. A number of Auto-trol employees who had been involved in the sales and support of MOSS joined Fiery in establishing Infrasoft in 1994.

About a year after Infrasoft set up shop in Danvers, Massachusetts, word began circulating that MOSS Systems was for sale. The expectation was that one of the major CAD players would acquire the company because of its underlying technology and large

[30] http://www.nxtbook.com/nxtbooks/bemagazine/ar2006/index.php
[31] I was responsible for the sales and support of MOSS at Auto-trol from 1985 through 1991.

 

worldwide installed base of users. Infrasoft, with just 10 employees at the time, offered to acquire MOSS System which had nearly 100 employees. It took almost 16 months to consummate the deal, but Infrasoft put together the financing and took over MOSS Systems in December 1996. Fiery recruited a strong board of directors including Dave Arnold - the founder and former CEO of Softdesk, James Burnley - former US Secretary of Transportation, and Viggo Butler - former CEO of Airport Group International. Other than the original founders who were looking to retire, Infrasoft retained virtually the entire MOSS Systems staff in the UK.

Starting well before the first computer was used for roadway design, engineers have used a technique involving cross-section templates to design highways and calculate earthwork quantities. It was no surprise when most software packages including InRoads and GEOPAK (in a somewhat modified manner) implemented the same basic technique. The problem with this approach is that while it works adequately for straightforward sections of highway, the template method is difficult to apply when designing complex roadways such as those encountered when working on multi-level interchanges or widening urban expressways.

The original MOSS developers took a significantly different approach. They decided to describe all geometry, whether it was existing terrain, proposed alignments or drainage channels, in the form of three-dimensional strings. A string is nothing more than a linked set of three-dimensional points in space. The result is an extremely flexible data structure that is amenable to virtually any design situation. Examples of roadway design strings would the centerline of the highway, the edge of shoulder, the bottom of curbs, the top of curbs and the outer extent of earthwork. While most of these are defined by the user, some, such as the outer extent of earthwork, are calculated by the software.

Infrasoft renamed the original MOSS software the MX Series with modules for road design (MXROAD), pavement renewal (MXRENEW), railroad engineering (MXRAIL) and site engineering (MXSITE). It worked with both AutoCAD and MicroStation although during the late 1990s, Infrasoft tended to prefer working with Autodesk since Bentley was a direct competitor with GEOPAK. Figure 10.3 shows the use of MXROAD to design a typical roadway intersection.

Bentley announced in January 2003 that it planned to acquire Infrasoft and a few months later the deal was completed. To some extent, Bentley may have made this move to keep Autodesk from acquiring Infrasoft and competing more effectively in the civil marketplace.

All three civil product lines were managed by Gabe Norona and development efforts were initiated to create new highway design applications that would eventually merge the best characteristics of packages into a new suite of civil engineering programs.

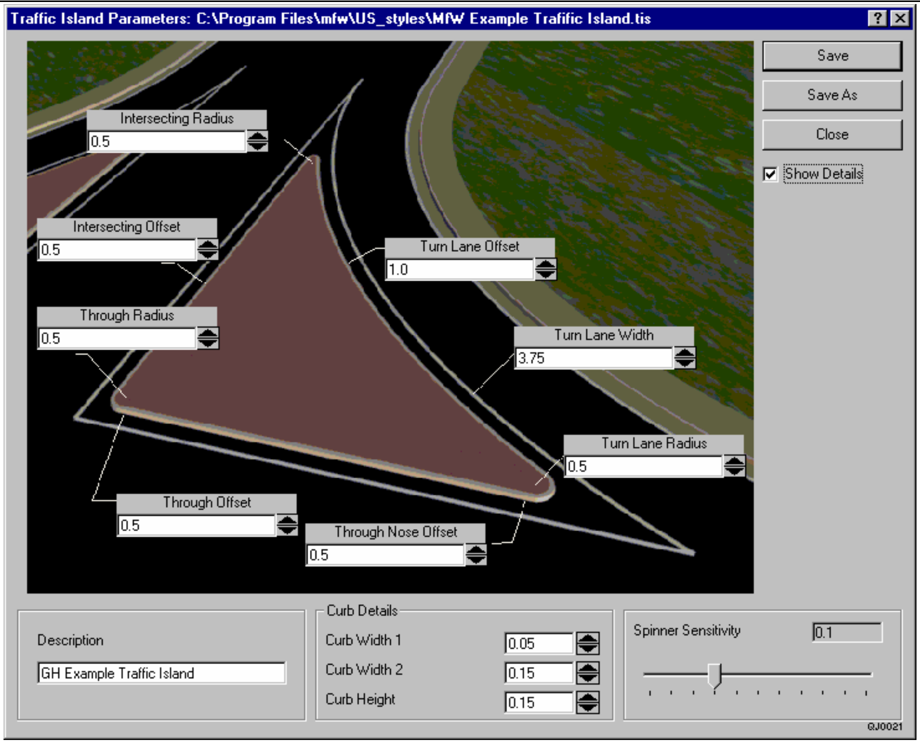


Figure10.3
Use of Infrasoft's MXROAD to a design roadway intersection

# Chapter 11

# CALMA

Author's n*ote: I was employed by Calma from February 1972 through October 1973 as a salesman, initially at corporate headquarters in Sunnyvale, California and subsequently in the Boston, Massachusetts area. Much of the early part of this chapter is based upon that personal experience.*

Calma Company was founded in Sunnyvale, California in1964 by Ron Cone, a former engineering vice president at CalComp, Cal Hefte, a distributor of CalComp equipment in the Bay Area, and Jim Lambert who was Cal's partner. The company's initial product was a device for digitizing oil and gas well strip charts. Subsequently, Calma began manufacturing large digitizers which could be used to capture data for other computer applications ranging from mapmaking to integrated circuit manufacturing. In this regard, it was very similar to Auto-trol Technology (See Chapter 9).

The typical Calma digitizer was 48-inches by 60-inches and used what was technically called a restrained cursor. The cursor mechanism was controlled by cable devices in the X and Y directions. These were well designed units that enabled the user to quickly navigate across a document taped to the digitizer table. The X and/or Y axis could be individually locked which made the units particularly applicable to digitizing semiconductor or printed circuit board (PCB) designs which tended to consist of predominately orthogonal shapes at the time. There was also an X/Y display module which showed the current cursor location and an alphanumeric and function button keyboard for entering commands and related data. Output was either punch cards or magnetic tape.

By the early 1970s, none of the three founders were actively involved with the company although Cone was still chairman of the board. The president was Bob Benders who had been hired from Lockheed's operation in Sunnyvale a year or two earlier. Benders had grown up in Europe during World War II and had a reputation as a tough but fair manager. He became president in 1971 and deserves much of the credit for making the company an industry leader by the end of the 1970s.

The initial Calma digitizers used hardwired logic. When Benders came on board, he personally directed the redesign of the product line to replace the hardwired logic with a computer based control methodology. The computer the company selected was the Data General NOVA 1200, the same computer being used at the time by Computervision. It was a 16-bit machine much like Digital's PDP-11. The early systems had a 12K memory expandable to 32K (words, not bytes). As with the earlier hardwired units, output was either to punch cards or magnetic tape. These digitizers were called CALMAGRAPHIC systems and they sold for $25,000 to $55,000 with the high-end units incorporating disk storage capabilities.

It was a fairly logical extension of the CALMAGRAPHIC product line to add a graphics terminal to the system so that data could be viewed and edited as it was being recorded. In mid-1969 the company hired a brilliant young programmer named Josef (Joe) Sukonick who had recently earned a PhD in mathematics from MIT to put together the software needed to create an interactive graphic system. The system he developed, mostly by himself, was called the Graphic Data Station or GDS. Introduced in 1971, it was similar to the disk-based CALMAGRAPHIC system with the addition of an 11" Tektronix storage tube display. As data was digitized, it was displayed on this terminal. Graphical data could be edited using the digitizer cursor mechanism and control functions were entered using a keypad device.

Figure 11.1
Bob Benders

The GDS systems were well designed from a hardware point of view. Two features were important to the company's sales efforts. CALMA built its own high-speed interface to the Tektronix display rather than use a slower industry standard interface. The result was the far faster display of graphic information on the display screen than what most competitors could accomplish. Storage tube displays required that the entire image be redrawn if anything changed on the screen other than adding data.

If the user deleted a line, the entire image had to be repainted. Digitized circuit layouts consisted of fairly dense data and repaint times would have been annoyingly long without this specialized hardware. The second feature was that the system was very stable. It was possible to disconnect the main power cord, stopping the system cold, and then plug the power back in. The system would continue right from where it was when it lost power. Try that with today's PCs!

The total system configuration complete with the GDS software for integrated circuit mask making but without a large plotter sold for a little less than $100,000. Additional workstations were $35,000 each and large flatbed plotters cost as much as $68,000. The system was designed to support up to six workstations.

It would probably be useful at this point to describe how integrated circuits were designed and fabricated in the early 1970s since the process is much different today. The first step was to create a functional design of the circuit in the form of a logic diagram. There were a few computer programs available at the time that helped designers analyze timing issues and the logical integrity of the circuit. The next step was to make a drawing of the circuit on large sheets of grid paper, using a different color to represent each layer of the circuit. This was similar in many respects to how printed circuit boards had been designed for a number of years.

The integrated circuit diagrams were several hundred times the size of the final semiconductor chip. In early 1972, these drawings were often 48-inch by 60-inch in size or larger. The next step was to produce a mask of each circuit layer the size of the actual circuit. Typically, there were four to eight different layers of material that were used to produce a circuit. Each mask master was carefully cut into a sheet of peel coat material (a popular brand was Rubylith, which is still used for graphics art applications) using a device that was somewhat like a reverse digitizer except that it was manually operated. If the operator wanted to create a rectangle, he or she would cut the four lines that made up the rectangle through the top material but not through the base material. The rectangular area was then created by removing the peel coat material within the scribed lines. This was a very time consuming process and easily susceptible to error.

The next step was to photographically reduce these sheets of peel coat material, each representing a different layer of the circuit, to the actual size of the integrated circuit. This was done using large fixed format cameras. The physical masks used for manufacturing the circuits were produced using a precise instrument called a stepper. This basically took the source film of the circuit layer and reproduced it as many times as would fit on a mask the actual size of the wafer. The typical wafer size in the early 1970s was four inches or less in diameter as compared to today's state-of-the-art 12-inch wafers.

There were several problems with this approach for producing mask sets used to manufacture integrated circuits. First, it was slow and prone to error. Although there were photographic techniques that could be used to verify the accuracy of the individual masks, problems often remained undetected until a test batch of circuits were produced.

Second, circuits were becoming increasingly complex. This was about the time that Intel's Gordon Moore came up with Moore's law which stated that the number of logical elements on a semiconductor chip was doubling every 18 months. The size of memory chips and microprocessors was starting to grow rapidly and it was fairly obvious that within a few years the industry would need a sheet of paper the size of a basketball court to lay out new circuits. Chips such as memory circuits had a large degree of repetitiveness to them but the existing manual process treated each memory cell as a separate element.

Third, instrument manufacturers were starting to produce equipment for making masks that were driven by digital data. The only way to use these instruments was to convert the artwork to a digital format. The result of these three issues was an industry ripe for automation.

**Calma becomes a major provider of systems to semiconductor industry**

Calma's vice president of sales was Tom Cain, an ex Navy Captain who lived in Bethesda, Maryland. He had been hired because much of CALMA's early digitizer sales had been to government mapping agencies such as the Army Topographic Command and the Air Force Aeronautical Chart and Information Center. I was hired by CALMA in February, 1972 to pursue business in the California and Arizona semiconductor industry. At that time, Calma had sold just one two-station GDS system to Intel. The company had literally no sales literature, no marketing and was up against several aggressive competitors in Applicon and Computervision.

Calma had the advantage that it was right in the middle of Silicon Valley. It also took a different approach to this market than Applicon and Computervision did. Calma focused on the manufacturing side of the semiconductor companies while Applicon, especially, focused on designing chip layouts. Applicon was represented on the West Coast by Dick Spann, one of the company's founders and a former Lincoln Laboratory software developer who eventually became president of Adage while Computervision was represented by Bob Gauthie who went on to be that company's vice president of marketing.

By late 1972, the functional capabilities of the GDS system had expanded considerably from when the first system had been sold to Intel. Initially, all it could handle was horizontal and vertical lines. Just doing 45° lines was a challenge. But the basic cell oriented architecture Sukonik had implemented was a solid design. Sukonick and the programmers who subsequently joined the company had the ability to add capabilities to the system without slowing down its basic display operations. This cell orientation also enabled the development team to expand the system to handle drafting applications including the ability to place text adjacent to or inside a symbol, justified horizontally and vertically. In a number of small incremental steps, the GDS system was becoming a basic drafting system.

Meanwhile, Benders worked hard at keeping the cost of CALMA's products under control. For example, the company was reluctant to increase the memory of the Nova 1200 from 8K to 12K words as the requirements of the GDS software grew. Computers used magnetic core memory at the time, not semiconductor memory, and an extra 4K words added several thousand dollars to the cost of a GDS system.

The major manufacturing problem the company had in those days was testing the hardware after a GDS system had been assembled. The primary component was a large back panel that contained all of the system's interconnection logic including the high-speed graphics interface and interfaces to peripheral devices such as plotters and digitizers. These panels were wire wrapped meaning that each end of wire was manually wrapped around a specific connector. Although the women who did this work were careful, errors did creep in and they were quite time consuming to find. CALMA used its system checkout process as a primary means of training field engineers. It served that purpose fairly well but it still took weeks to check out each system. The advantage of using a wire wrapped approach was that design changes could be made quickly and if necessary, incorporated into systems already in the field.

Calma supported a number of different output devices. The typical system included either a CalComp drum or flat bed plotter or a Xynetics flat bed plotter that were used to produce check plots. The CalComp flat bed plotter could also be equipped with a cutting mechanism to produce IC mask masters using the peel coat material described earlier. The Xynetics plotter, on the other hand, was a very fast pen plotter that used a magnetic technique to hold and move the plotting mechanism. Calma also developed software to drive optical devices such as those manufactured by the D. W. Mann Corporation, for producing mask layouts. By mid-1973, Calma had sold GDS systems to a number of semiconductor manufacturers and service companies that handled mask making tasks for the industry. In addition to Intel, customers included National Semiconductor, Motorola, Rockwell, MicroMask and Transmask.

At this point, the company was generating sufficient revenue that it was able to beef up its engineering and software development activities. One of the first steps was to create an edit station that used a Computek tablet and stylus instead of a large digitizer as the user input device. Substantial progress was also made in expanding the GDS software to include basic drafting and printed circuit board layout and artwork generation. In addition, the development of a mapping application was initiated under the direction of Roger Sturgeon. One of the industry's first user-oriented development languages, the Graphics Programming Language or GPL, was introduced in 1974 and the ability to handle integrated circuit elements at any angle followed in 1975.

**The development of a new mechanical CAD system**

As mentioned in Chapter 12, Calma hired David Albert and many of the former Computervision programmers in San Diego in 1976. Most of these individuals had turned down Computervision's offer to move to the Boston area when that company decided to consolidate its software development operations. Initially, Albert and his associates considered starting their own software company and one of their first potential clients was Calma. In addition to Albert, the primary members of this team were Jerry Devere, Glen Peterson, Ron Ianneta, and John Kaufman. Art Colmeyer, who was the head of Calma's R&D activity at the time suggested that they join Calma as employees rather than work as contractors. After several months of negotiations, the San Diego group became part of Calma and set about developing a new CAD system.

The resultant product, called DDM (Design Drafting and Manufacturing), was introduced in 1977. Users could display up to six independent views of a three-dimensional model and a change to any one view would immediately be reflected in the other views. Geometric construction operations could be initiated in one view and continued in another view. Hidden-line software was particularly fast and model views could be displayed with hidden lines suppressed or displayed in a separate line font. Hidden lines could be displayed differently in the six independent views and the six viewports could also have separate scaling. A user interacted with the system using either a digitizer-equipped workstation or a design/edit workstation that utilized a tablet and stylus or pen. All commands were displayed on the digitizer or tablet menu. These menus were supplemented by keyboard command entry and a programmable 32-function keyboard.

DDM was initially written to run on Data General computers, much like the company's other systems. It was written in FORTRAN V and used a modified version of Data General's Real Time Disk Operating System (RDOS). Each workstation incorporated two displays, one for graphics and one for alphanumeric data. This setup was dictated by the fact that the Tektronix storage tube displays then in use were not conducive to showing rapidly changing alphanumeric information. It was a similar configuration to what Calma used for its other applications. The alphanumeric screen primarily provided user prompts including a list of options for the command currently being executed.

Fast system response time had been a hallmark of Calma systems since the early 1970s and DDM was consistent in regards to this software and hardware characteristic.

DDM may well have been the first mechanical CAD system that stored geometric data in a double precision 64-bit format. The company's sales literature claimed that DDM could display three-dimensional models faster than competitive systems could display two-dimensional images.

A user development language called DAL (Design Analysis Language) was an integral part of DDM from the start. DAL provided user access to all DDM commands unlike some competitive systems which restricted which functions could be incorporated into user programs. DAL was also used to group repetitive sets of commands so they could be executed in one operation, incorporate scientific formulas into geometry creation operations, and interface DDM to existing FORTRAN programs. DAL created an intermediate object code that did not require recompilation each time it was executed. Instead, it ran in a interpretive manner similar to the way BASIC programs were run at the time. These programs could be saved in a library and executed by name or by assigning them to menu items. The company's promotional literature claimed that productivity increases in the area of 7 to 1 were typical and that improvements of 50 to 1 were being achieved using specialized DAL programs.[1]

DDM was basically a wireframe modeling system with surface geometry capabilities. The surface geometry software was developed working with people at the University of Utah and it handled planes, cylinders, surfaces of revolution, ruled surfaces, tabulated cylinders and sculptured or free form surfaces. Surface geometry was an optional package which was required for the hidden line removal operations described above. See Figure 11.2. Among the other DDM applications provided by Calma were packages for doing kinematics and finite element modeling as well as numerical control tape preparation. The latter program generated tool paths for profiling, pocketing, lathe operations, and 3-axis and 5-axis surface machining.

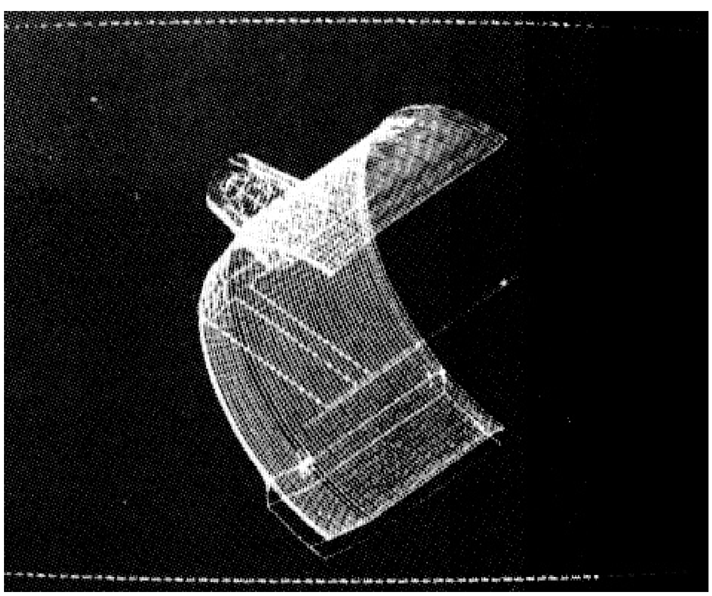

Figure 11.2
Calma DDM Surface Geometry

[1] *DDM from Calma* – undated company brochure after acquisition by United Telecommunication in 1978

**Sale of Calma to United Telecommunications**

On August 31, 1978, Calma was acquired by United Telecommunications for approximately $29 per share or about $19 million. United Telecommunication is known today as Sprint Corporation, a major provider of mobile phone services. The following table shows the Calma's financial growth through the 1970s. The company's fiscal year ended August 31st. The major problem is that the company never seemed to have much cash (less than $20,000 on August 31, 1977) and accounts receivable were typically huge, often running over 150 days of sales.

| Fiscal Year | Revenue | Earnings |
|---|---:|---:|
| 1971 | $670,000 | ($293,000) |
| 1972 | 1,586,000 | 179,000 |
| 1973 | 3,462,000 | 412,000 |
| 1974 | 6,146,000 | 562,000 |
| 1975 | 6,919,000 | 438,000 |
| 1976 | 9,484,000 | 747,000 |
| 1977 | 14,279,000 | 1,230,000 |

After United Telecommunications acquired Calma, it took a hands off approach to the company's management. The existing management team stayed in place including:

- Bob Benders – President
- Lemuel Bishop – Vice president, finance
- Dr. Arthur Collmeyer – Vice president, research and development
- Eugene Emmerich – Vice president, marketing
- Paul Kemp – Vice president, sales

In late 1979, the company's primary business continued to be systems for electronic artwork generation for both integrated circuit design and PCBs. Calma was perceived by most observers at the time to be the largest vendor of graphic systems to the semiconductor industry. GDS software was ported to 32-bit Data General computers in 1978 and the company began offering software to support electron beam pattern generation machines. This was followed in 1979 by the introduction of high-resolution color graphics terminals and support for high-speed electrostatic plotters. A typical storage tube workstation of that era is shown in Figure 11.3.

The company was also starting to develop a significant presence in the mechanical CAD market as well as selling systems for mapping and engineering design. In these latter areas major customers included Brooklyn Gas and Electric and Ontario Hydro. Calma was growing rapidly with sales nearly doubling every twelve months and with about 500 employees, 1979 revenues were estimated to be about $40 million. This was about the same revenue level that Applicon, Auto-trol Technology and M&S Computing (Intergraph) had at that time.

Figure 11.3
Calma Digitizer Workstation with Storage Tube and Alphanumeric Display Console

**Expanding DDM into the AEC Market**

In early 1980 Calma was organized into two business units, a Microelectronics Division with Collmeyer as vice president and general manager and a Mechanical Division with Ronald Hill in the same position. The Mechanical Division was also responsible for the development and marketing of systems targeting the AEC market. Although older Calma system could be used for basic drafting applications, there was a need for more advanced design technology, especially in the process plant design area.

The plan was to develop a series of design applications for the AEC market that would use DDM as underlying geometric modeler. The project was called CADEC (Computer-Aided Design/Drafting/Documentation for Engineers and Constructors). Modules under development included architectural drafting, civil engineering including terrain modeling, structural and process engineering including flowsheets, P&IDs, piping, mechanical, electrical and HVAC. It was a rather ambitious undertaking and one which did not have a lot of industry visibility. The lead manager for this effort was Jim Lambert who held the title of Director, AEC Systems.

By mid-1980, CADEC had progressed to the point where Calma had six beta test sites using the software, three in the United States and three international. The lead American user was Stone & Webster in Boston. Eventually, CADEC would morph into Calma's Dimension III product described below.[2]

**General Electric enters the picture**

In December 1980, less than 30 months after it had acquired Calma, United Telecommunications agreed to sell the company to General Electric for up to $170

[2] *A-E-C Automation Newsletter,* August 1980, Pg. 6

 

million in cash. This consisted of a $100 million cash payment upon closing of the sale and up to $70 million payable in the 1985 timeframe based upon Calma's revenue during the subsequent four years. United had decided that Calma's systems manufacturing business simply did not fit in with its other computer services activities.[3] Even without the additional payment, this was fairly nice profit on the latter company's $19 million investment.

Prior to the deal closing in early April 1981, the Federal Trade Commission expressed concern that GE's ownership of nearly 23 percent of Applicon and its acquisition of Calma were anticompetitive. While it is not clear that its subsequent actions were the result of a direct request from the FTC, GE soon announced that it would sell the 1.2 million shares of Applicon that it owned within the next 12 months. 1980 had been a good year for Calma. Revenue was up to $62 million, the company entered 1981 with a $17 million backlog and Calma's 1,000 employees were ensconced in a new facility in Milpitas, California that included a 204,000 square foot manufacturing plant.[4] On a revenue basis, the company was competing for third place in the industry with Intergraph, chasing after Computervision and Applicon which held first and second position.

One of the first steps taken to provide GE resources to Calma was to establish a communications link between Calma's DDM software and software offered by General Electric Information Services Organization. GEISCO was one of the leading time-sharing companies at the time and offered its customers NC post-processing services among other applications. It also offered APT part programming on a timeshared basis. While these services were available to all manufacturing companies in one fashion or another, having both Calma and GEISCO under one corporate roof provided addition marketing clout for Calma's sales organization.

Acquiring Calma was not a random move on the part of GE. The company was in the process of putting together a group of corporate organizations to market products and services for what it referred to as the "Factory of The Future." The company's position was that computer and communications systems were going to have a major impact on how manufacturers designed and produced products in the future and it intended to be a major force in that market.

In retrospect, it was a totally rational concept and one that eventually proved to be true. Under Jack Welch, the corporate attitude at GE was that a company was either number one or number two in a particular market segment or you got out of that business. GE proceeded to pour millions into Calma to expand its product development and marketing activities but it was never able to make the company profitable. During the seven years it owned Calma, losses ran as high as $50 million annually.

While United Telecommunications had taken a fairly hands off approach towards managing Calma, GE set out fairly quickly to make it a "GE" company. This did not set well with many of Calma's managers. A good example was Harvey Jones who had joined the company in 1974. After a stint in the company's development organization, Jones took on increasingly important roles in the sales and marketing of Calma's electronic design and artwork generation products. After receiving an MBA from MIT's Sloan School, Jones was promoted to vice president of business development for the

[3] Barbetta, Frank, *Electronic News*, December 8, 1980, pg. 1
[4] *Electronic News*, April 6, 1981, pg. 91

 

## General Electric's Factory of the Future

Jack Welch became chairman of GE on April 1, 1981, about the same time that the company completed its acquisition of Calma and announced the factory of the future business initiative. GE is deservedly respected as one of the best managed companies in the world. That does not mean that everything it touches turns to gold. The factory of the future is an excellent example that even well managed companies can screw up on occasion. When GE launched its plan, it seemed like the ideal company to do so since it not only sold a wide variety of technical products, but it also was a major manufacturer in its own right with plants that made everything from household appliances to locomotives.

The plan was to bring together in a single organization all the technical components needed to automate industrial factories. Several of the necessary products lines including industrial drives for operating metal and paper mills and controls for milling machines were already part of GE's extensive product line. Other elements, such as robotic equipment, would be sold under license from other manufacturers and some, such as factory floor communications systems, would be developed internally. Calma would provide the tools to design the products these automated factories would produce. GE's top management perceived this as an opportunity to provide large industrial companies with "one-stop" shopping.

The automation group, formally called the Industrial Electronics business group, was initially run by Donald Grierson, a GE executive who clearly was on a fast track within the company. Prior to taking on this assignment he had held five different positions at GE in five years. While he was perceived within the company as being a thoughtful strategist, he left something to be desired when it came to the details of running a business and the automation group was a very complex business. Part of the problem might have been the fact that while the group's headquarters was in Charlottesville, Virginia, the operating activities were scattered around the country. In the early 1980s, many of the tools we take for granted today for running decentralized organizations simply were not available. Grierson was definitely enthusiastic about the potential in this area. In one press release he is quoted as stating that "GE intends to 'blast productivity figures through the roof.'"[5]

In retrospect, GE's eventual failure in this area can be attributed to trying to do too much too quickly. The company set very high revenue goals and promised prospects a suite of advanced products that took far longer to develop than initially contemplated. The result was that some of these products, such as a factory communications system, were plagued by reliability problems. The company initially promised prospects that it would guarantee complete factory automation solutions including equipment such as machine tools for which it was simply acting as a reseller. When it came time to deliver on such promises, GE got cold feet.

[5] Calma press release, May 5, 1981

 

> The automation group lost over $120 million between 1982 and 1984 according to *Fortune*. This was far more than what GE had planned when it launched the initiative. Grierson left GE in July 1985, initially to become a private investor and eventually to join ABB Vetco Gray, an oil services company, where he was president and CEO until 2002. He has also been on the board of directors of Parametric Technology since 1987. As described below, Calma was separated from the automation systems group in 1984 and eventually, GE took a much more low key approach to the whole subject of factory automation systems. Nearly 20 years later, one can look back at its efforts in this area and see that the company was simply ahead of the market's willingness to accept such a broad overhaul of its fundamental manufacturing infrastructure.[6]

Microelectronics Division. Shortly after GE acquired the company, Jones left Calma to co-found Daisy Systems, one of the first workstation-based computer-aided engineering (CAE) companies. After a stint as vice president of sales and marketing and then as president of Daisy he went on to become president of another CAE start-up, Synopsys – a major CAE firm. This was the type of talent the company could ill afford to loose but something that would occur repeatedly over the next few years.

The personnel changes came fast and furious as other long term Calma players decided that the GE administrative environment was not for them and as GE brought in its own people, some from within GE and some new hires. In June 1981, Jeffery Lane was brought in from Boeing as manager of advanced product development and John Benbow was hired from Dataskil to be vice president of research and development. Art Collmeyer, who had been with Calma since 1974 and was vice president and general manager of the company's Microelectronics Division left before the end of 1981 to start Weitek, one of the first fabless semiconductor manufacturers. Jim Girand, who had been vice president of sales for this division took over Collmeyer's job. He stayed around until early 1983 at which point he also left to join Weitek. Roger Sturgeon, who had joined the company in the early 1970s and had been responsible for developing the GDS II system left, along with Tom Bakey, to join TRICAD, a new startup targeting the AEC market. This latter company was subsequently acquired by Auto-trol Technology in November 1984.

In the fall of 1981 Calma replaced Applicon as SDRC's preferred CAD/CAM partner. GE and SDRC agreed to establish five Productivity Centers in the United States and Europe equipped with Calma CAD/CAM systems along with GE robotics equipment and NC controllers. Customers could either hire SDRC to handle design and manufacturing projects or could do it with their own personnel. GE's strategic objective, of course, was to raise the level of awareness among its customers for this new breed of technology in the hope that it would become the primary supplier of design and factory automation tools to those companies.[7]

At the November 1981AUTOFACT conference in Detroit, Michigan, GE's master plan for Calma and the factory of the future began to take shape. A number of new CAD products were demonstrated in a scaled down version of a Productivity Center as well as a preview of a new solids modeling package, DDM/Solids. GE supposedly spent

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[6] Petre, Peter, "How GE bobbled the factory of the future," *Fortune*, November 11, 1985, Pg. 52

[7] *Anderson Report*, November 1981, pg. 1

 

$1.6 million on this one trade show.[8] In January 1982 GE acquired a 48 percent interest in Structural Dynamics Research Corporation (SDRC) and began integrating SDRC's mechanical CAE software into the Calma product line.[9] In addition to this arrangement, GE acquired a majority interest in CAE International. It was now 51 percent owned by GE and 49 percent owned by SDRC. The word being spread was that GE was prepared to invest over one billion dollars in its factory of the future initiative and that CAE International and Calma were key elements of that plan.

The general concept was that SDRC would provide the tools for conceptual design and analysis, Calma would provide the systems for converting those designs into the information needed for manufacturing them and other GE divisions would provide factory automation.[10] It was a great concept that never seemed to quite come together. Confusing the situation described above was the fact that Calma had recently announced its own solids modeling software called DDM/Solids. This package was initially implemented on 16-bit Data General systems and subsequently ported to 32-bit DEC VAX machines. The product never took off and was replaced by an agreement for Calma to market SDRC's GEOMOD. It turns out that DDM/Solids was not really a solids modeler but simply produced shaded images of surface defined models.[11] For the next several years, the two companies had separate sales organizations that only loosely coordinated their activities.

Calma's marketing personnel sometimes got carried away when describing the company's products and business developments. For example, in December 1981 Calma announced that it had established an AEC division and claimed that it was "the only CAD/CAM maker with a division totally dedicated to the AE&C market."[12] That probably came as a surprise to competitors such as Computervision and Auto-trol Technology that were already organized in a similar manner although they may never have used the term "division.." The head of Calma's AEC Division was Dr. Ronald Hill who had joined the company in 1978. Hill was previously with Tektronix.

**Broadening the Calma's product line**

Starting with its earliest computer-based systems in 1971, Calma had used Data General computers. In the fall of 1982, the company was still using Data General Eclipse computers but was exploring the possibility of supporting both Apollo workstations and DEC VAX computers, especially for its mechanical and AEC software products. There were three versions of the Eclipse hardware at this point. The Series 1000 was a single cabinet configuration that supported two workstations, the Series 2000 was a single or dual processor system that supported up to six workstations while the Series 170 was a low-cost single workstation system introduced in September 1982. Calma provided high resolution (1280 by 1024) color and monochromatic workstations plus a low resolution (640 by 512) color unit. Calma's typical workstation had two displays, one for graphics information and one for alphanumeric data. The exception was the Series 170 which utilized a single screen configuration. The typical Series 1000 and Series 2000 system

[8] Petre, Peter, "How GE bobbled the factory of the future," *Fortune*, November 11, 1985, Pg. 52
[9] *Anderson Report*, December 1981, pg. 2
[10] *Anderson Report*, September 1982, pg. 3
[11] *Computer Aided Design Report*, October 1986, Pg. 14
[12] Calma press release, December 1, 1981

sold for about $125,000 per seat not including a plotter output device while the 170 was priced just under $100,000..

The DDM software included optional modules for finite element modeling, solids modeling and plastic injection mold design and analysis. The solids module used a boundary representation technique that created models compatible with existing DDM databases. The company also tried to blend its mechanical and electronics activities together to some extent by introducing DDM/PC, a software package that supported printed circuit board design using the same data base that was used by DDM for mechanical design.

In addition to its dominating position in the electronics CAD market and a growing involvement in the mechanical sector, Calma was also pushing ahead in the AEC market, especially in regards to process plant design. The company's primary product in this area, initially released in 1981, was called Dimension III. This was the production version of what had earlier been called CADEC. Release 2 of the Dimension III software began shipping in early 1982. It included automated piping design based upon user input of pipe specifications and routing.

In mid-1982, the Dimension III product suite was expanded with packages such as electrical schematics, including the generation of signal net lists and from-to reports, civil site preparation, general mapping and steel layout, design and detailing. Although the company offered two-dimensional architecture and facilities layout programs called Calma-Draft Architecture and Calma-Draft Facilities Layout, Calma never pursued the pure architectural design and drafting market with any vigor.


Figure 11.4
Calma Dimension III Systems – Rich Tate, Calma Applications Engineer

The microelectronics portion of the product line continued to use the overall GDS nomenclature. Specific applications included CARDS for printed circuit board design and analysis. It incorporated design rule checking, interactive routing and support for up to 64 layers. A subsequent version called CARDSII added hybrid circuit design capabilities. CHIPS was the comparable software for the geometric design of integrated circuits while STICKS was the company's first attempt to develop a symbolic design methodology for VLSI circuits. STICKS was subsequently renamed CustomPlus. The company was an early user of Apollo workstations which when combined with a logic design system called CIRCUITS, sold for $75,000.

One area where Calma was an industry pioneer was in the use of voice recognition for the entry of user commands. Introduced in 1980, it initially required the use of Calma's Vector Memory Display (VMD). With the availability of GDS II Release 4.0, voice input was available with all Calma raster terminals. The early voice recognition system had a vocabulary of 100 commands. Few organizations ended up using this technology, however. In 1982, Calma also introduced its first communication networking package called CalmaNet which could link together a variety of systems and applications.

In the fall of 1982 Calma's sales force was still operating independently of GE but *The Anderson Report* expected GE to raise the level of contact these sales people had among its customers. In its September 1982 edition, the newsletter stated:

> "The rate of growth in the microelectronics area is slowing but Calma is well positioned with DDM based products to take advantage of the high growth in the mechanical application. We predict GE/Calma will be the first or second ranked supplier of turnkey CAD/CAM systems by the end of the decade. IBM has more sales muscle but GE is better positioned in terms of products for the automated factory."[13]

Bob Benders initially stayed on as president of Calma under GE and the R&D budget doubled to 25 percent of revenue.

**Early signs of problems**

In early 1983, Jim Girand left to join Wietek and Ken Tisovec became vice president of sales. Then in April 1983, Calma announced what would be become a continuing series of staff reductions. It was just 40 employees but the move was not a good sign. At the same time, Bob Benders resigned as president of the company he had headed for nearly 15 years. Benders was replaced as president in March 1983 by Robert Smuland, a 25-year GE veteran. Like Schlumberger and its Applicon subsidiary, GE seemed to believe that any experienced executive could manage a company such as Calma even though that person was new to a rapidly changing high tech industry.

In fairly short order, an entire new management team was recruited from other GE divisions including:

- Dr. Mark Baron as vice president of research and development (from GE's Microelectronic Center),
- Dr. Charles Cheeseman as vice president of marketing and product management (from GE's Electronics Systems Division),

[13] *Anderson Report*, September 1982, pg. 6

 

- George Senn as vice president of operations and product support (from GE's Nuclear Control and Instrumentation Department),
- Gerald Knudson as vice president of sales (from GE's Medical Systems Operations) and
- Richard Overholtzer as vice president of finance (from GE's Nuclear Business Group).

If anything, this team was probably overqualified for managing a subsidiary the size of Calma. In addition, they had little experience with CAD technology and the commercial software industry. Lief Rosqvist, who had moved to the U. S. in 1982 from Sweden to be Calma's vice president of marketing was switched to vice president of business planning and development. Not every new executive came from within GE. David Richards was hired away from Arrigoni Computer Graphics to head up the company's AEC business unit. Other key individuals were Jerry Devere who was now running the San Diego software development operation in place of David Albert and Dr. Malcolm Davies who was vice president of the AEC products group and would later leave and become a senior executive at Autodesk.

**Calma's product line becomes more complicated**

June 1983 saw Calma re-emphasizing its commitment to Data General hardware when it announced that GDS II would be supported on DG's Eclipse S280 minicomputer. Calma's nomenclature for this machine was the P 4280. The situation became somewhat clouded in September 1983 when Calma added the TEGAS suite of electronics CAE software after its acquisition of CGIS, an engineering subsidiary of Communications Satellite Corporation (COMSAT) located in Austin, Texas for $14 million. TEGAS ran on Apollo workstations which Calma was already using to support some of its mechanical design and schematic capture software packages. Around the same time, Calma established an R&D group called Calma Advanced Systems in Troy, New York at Rensselaer Polytechnic Institute. It is interesting to note that GE's primary technology center for the "factory of the future" was just a few miles away in Schenectady.

In the hardware area, Calma made another major change in direction and signed an OEM agreement with Ramtek worth $20 million over a period of several years for that company's 2020 color raster displays. Calma had been using Lexidata graphics hardware for its raster terminals and would continue to do so for several more years as it phased in the Ramtek products. The Apollo portion of the company's product line was called the D 3200 Series. It encompassed three types of nodes, S (Standard), D (Distribution) and P (Peripheral). The latter two were basically server nodes. Because much of Calma's software was written to support separate graphics and alphanumeric displays, the D 3200 S nodes included a separate alphanumeric display.

According to Dataquest, Calma's revenue in 1983 was $210 million of which $105 million was mechanical, $82 million was electronics and $23 million was AEC. Over half the mechanical revenue and a significant portion of the electronics revenue came from sales to other GE divisions. Revenues for 1984 were expected to be in the range of $250 million.[14] In reality, 1984's revenues ended up being essentially flat or

[14] Personal notes dated November 19, 1984

 

down somewhat compared to 1983 and 1983 may well have been the company's high water mark.[15]

The relationship between GE, Calma, SDRC and the jointly owned CAE International was confusing at best to outside observers. At the National Design Engineering Show in Chicago in March 1984, Calma and CAE International announced a jointly developed mechanical CAE software product based upon SDRC's I-DEAS modeling and analysis software including SDRC's GEOMOD solids modeler. A direct translator between the two product lines was promised for delivery in October while IGES translators were scheduled for release in May. Starting in 1985, Calma began selling another SDRC software package, GEODRAW, which enabled users to directly dimension and annotate solid models created in GEOMOD. There was no bi-directional associativity in that changes made in GEODRAW were not reflected in the source GEOMOD model.

This software was available on both VAX and Apollo hardware. The plan contemplated that designs developed in GEOMOD could be transferred to Calma's DDM system for detailed design and documentation while SDRC's analysis software would be used to evaluate these designs. The CAE International software was sold either bundled or unbundled while Calma's DDM software continued to be sold only bundled with computer and graphics hardware. In addition to the plans for tying the software from the two firms more closely together, it was also announced that a single sales organization would replace the previously independent CAE International and Calma sales forces focused on the mechanical market. The word was that this latter move was directly in response to input from Jack Welch.[16]

**New relationship with IBM**

In 1983 Calma began discussing with IBM the possible use of the latter's computers as the database management element of its systems. According to Dr. Charles Cheesman, Calma's vice president of marketing and product management, "Now, because of new technology, it's time for engineering to link in the analysis programs and to do background processing (whether analysis or data base management). That takes a big, husky CPU."[17] In June 1984 Calma announced that it would resell IBM's 4300 Series computers together with Calma software for data management applications. This was similar to an agreement Computervision had with IBM for the same type of application.

Later in 1984 Calma expanded its European operation by buying a 108,000 square-foot facility near Dublin, Ireland that had originally been built for Trilogy Ltd., the Gene Amdahl company that had planned to build computers using wafer-scale integrated circuits.

The fall of 1984 also saw the introduction of new DDM software for generating families of parts. The new software was called Parametric Analysis Level (PAL) and worked in conjunction with DDM's DAL software. To generate a family of parts the user first designed a sample DDM part with the PAL software engaged. PAL recorded a DDM

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[15] *Computer Aided Design Report*, December 1984, Pg. 9

[16] Vinton, Bob, "GE's CAEI/Calma Opns. Introduce Turnkey System," *Electronic News*, April 2, 1984, Pg. 79

[17] Unfortunately, I was unable to find the source of this quote

 

session and created a variable table that listed widths, lengths, thicknesses and other key dimensions. After completion of the sample part, the PAL recording was converted into a DAL program.

When the user needed a new part, this DAL program would be initiated, values entered for the variable dimension and the DAL program executed to generate the desired part. Although similar DAL programs could be created directly by users, PAL did not require knowledge of DAL programming, making it a more efficient technique that could be used by any DDM knowledgeable user. PAL was initially available on DEC VAX and Data General systems in early 1985 and was priced at $17,500 including installation and training.

In November 1984 Smuland was replaced as president of Calma by a former IBM executive, Dr. Daniel McGlaughlin. McGlaughlin, who had been recruited by GE several years earlier. He had been vice president of corporate information systems at GE prior to being assigned responsibility to run Calma. Smuland moved over to GE's Marine and Industrial Engines and Service Division as vice president and general manager.

At the same time as the management change, the company reduced its workforce by 15 percent or 305 employees. While Smuland had reported directly to Don Grierson, a new organizational structure was put in place which had McGlauglin reporting to a newly-established Calma board of directors made up of five senior GE executives. It's chairman was Edward Hood, Jr., the vice chairman of GE, who reported directly to Jack Welch. McGlaughlin had an excellent background to head Calma with a Ph.D. in electrical engineering from Case-Western Reserve University and 24 years of experience at IBM.

**Overview of Calma's product line in late 1984[18]**

In late 1984, Calma was offering software for three markets, electronics, mechanical and AEC. As described elsewhere, the primary electronics package was GDS II which still ran on Data General computers. The GDS II software suite included CHIPS (IC design), CARDS (PCB design) and STICKS (IC conceptual design). The TEGAS logic simulation software ran on Apollo workstations. DDM was targeted at the mechanical market while Dimension III was the AEC product.

Calma provided three computer platforms. The Series D was based on Apollo workstations. At this point in time, just the DN460 and DN660 machines were supported. The Series P consisted of Data General ECLIPSE computers while the Series C systems were DEC VAX machines. Each of these product lines consisted of a core module referred to as the System Base Group or SBG. To this was added various peripheral devices and in the case of the Data General and DEC computers, graphic terminals.

A variety of monochromatic and color terminals were available. By late 1984, workstations with both a graphics display and an alphanumeric display, the RB-1010 and the RC-1010, were being phased out and were being replaced with single screen units, the CDS-70X and the CDS-80X. The latter units were powered by Motorola 68000 microprocessors and were equipped with 1280 by 1024 monitors. An Ethernet capability called CALMANET was available to link all these different systems together. During this period it was never clear as to which was the preferred platform although it was obvious

[18] Based on author's personal notes

that the Data General portion of the product line had a very limited future. It seemed as if Calma was willing to simply let the customer chose between Apollo and DEC hardware.

DDM software was being sold in four versions, DDM-100 for drafting, DDM-200 for design, DDM-300 for manufacturing and DDM-400 for schematics. Perhaps this package's strongest feature was its DAL language which impressed even the company's competitors. DDM/Solids was no longer being marketed. Instead SDRC's GEOMOD software was the primary solids modeling package pushed by Calma. The company was also pushing a data management package developed by SDRC called Data Management Control System (DMCS). This software would later morph into SDRC's Metaphase (See Chapter 17). Dimension III was basically DDM software with AEC extensions written mostly in DAL. These applications included piping design, electrical schematics, steel detailing, etc.

A new mechanical system built around a solids modeling core was under development by the company's San Diego software operation under the guidance of Devere. Other developments included a new workstation using a Ramtek 2020 display, a factory floor communications network GE was jointly developing with Ungermann-Bass, a personal computer-based system and a new data management system to replace DMCS.

A typical color Apollo DN660 workstation with DDM or Dimension III software had a list price $67,500. Data General systems started at $170,000 while a VAX 11/780 system cost over $500,000. CDS-80X color workstations for the latter two types of systems were $60,000 while monochromatic CDS-70X units were $40,000 each.

**Start/Stop business momentum**

Although GE had acquired Calma primarily to drive the factory of the future, the company was starting to make significant strides with its AEC products. Calma won a major competitive order for Dimension III systems from Ingalls Shipyard in Pascagoula, Mississippi, signed a multi-year contract with Fluor Corporation and sold a $2.7 million system to Chicago's Commonwealth Edison. The company continued to invest in developing its plant design technology including signing an agreement with Imperial Chemical Industries to market ISOGEN, an software solution for creating isometric piping diagrams although it was mid-1986 before Calma actually began shipping an ISOGEN-based package.[19] In late 1985, the company signed a $7.8 million deal with China National Import Corporation for 60 Apollo-based Dimension III systems to be used at13 locations for modernizing power and process facilities.

Early 1985 saw Calma begin to respond to the market demand for updated GDS II systems. A 32-bit GDS II workstation incorporating Data General's MV-4000 computer and a Lexidata color display was introduced in January. Called the GDS II/32, it was priced at $95,000, 30 percent less than the list price of the older system it was intended to replace. This was not a stand-alone system – it required connection to an existing 16-bit GDS II system for background tasks such as plotting.[20]

In April 1985 Calma pulled out of the NCGA Conference in Dallas and the show floor space was used by SDRC and GE/CAE. About the same time, Welch approved a $100 million cash infusion in Calma with specific instructions to become the number two

[19] Calma press release, June 24, 1986
[20] *Computer Aided Design Report*, February 1985, Pg. 13

company in the CAD industry or at worst number three and to do so within three years. It never happened.

To expand its mechanical market coverage, Calma introduced a sheet metal package that could be used with existing assembly modeling software. What was really confusing, however, was the previously mentioned plan to market SDRC's GEODRAW, a two-dimensional drafting package that supported GEOMOD solid models. This was clearly competitive with DDM drafting software.

By the fall of 1985, Calma was aggressively pushing the Apollo portion of its product line. Virtually all of its software packages except for GDS II were available on these workstations including DDM, Dimension III, TEGAStation and T-BOARDS. While competitors such as Auto-trol Technology were promoting Apollo's lower cost systems, Calma emphasized the high-end DN660. Systems based on this color workstation were priced between $72,000 and $112,000 per seat.[21] By mid-1985 the company had installed a total of 1,600 systems of all types at 800 customer sites. The typical system probably had an average of four to six seats meaning that there were somewhere between 6,400 and 9,600 Calma users worldwide.

After going through the major layoff in late 1984 and another one in the spring of 1985, Calma surprised most of the industry a few months later in August 1985 with the announcement that it was going to increase its R&D organization by 50 percent and in the process hire 200 engineers by the first quarter of 1986. At the time, approximately 450 of Calma's 1,800 employees were engaged in product development activities. Most of the existing R&D staff was located at either corporate headquarters in Milpitas, at a software development facility in San Diego or at a facility in Austin, Texas. Calma also had access to GE's corporate research facility as well as other divisional research laboratory's throughout the company. In the 1985 time frame, GE in total spent over $2.1 billion annually on research and development.

**Trying to get Calma back on track**

The early part of 1986 may have represented a highpoint in GE's attempt to get Calma back on track. *The Anderson Report* described quite clearly in its February 1986 issue how GE had stumbled with its acquisition of Calma.

> "GE clearly over estimated the market for 'the factory of the future.' Buyers were not willing to risk major changes that could cripple production lines if the changes didn't work.[22] Although GE is a leading technology company, they did not understand the CAD/CAM business. In a traditional manufacturing operation, if you throw more money in, more product comes out the end. Not so in high tech. GE provided plenty of money, but not computer savvy managers. As a result the technical staff at Calma was decimated."[23]

[21] Calma press release, September 19, 1985

[22] The same comment was made 15 years later by many analysts who commented on the collapse of the e-commerce boom in 2000.

[23] *The Anderson Report,* February 1986, pg. 3

It took some time, but McGlaughlin was starting to have a positive impact on the company. He hired Stuart Elder from IBM to take over research and development activities and by early 1986 had hired half of the new 200 engineers mentioned above. McGlaughlin was also working hard to control costs. He had reduced headcount from 2,400 employees to about 1,600 and the company's revenues were holding steady at a little over $200 million.

**Electronics products continues to struggle**

The biggest problem at Calma was that its market share in the electronics-related area was slipping and was showing signs that it would continue to deteriorate. From 45 percent of the company's business in 1984, it shrunk to 35 percent in 1985. While the company still had a 70 percent share of the integrated circuit layout business, that market was quickly shifting to a new generation of CAE technology. Calma was critically slow in reacting to the change in technology, possibly because of GE's focus on the mechanical manufacturing market. Another negative factor was that the automated testing of integrated circuits was taking on increased importance. Systems that incorporated logical definitions of such circuits were more able to provide information for testing than graphics-centered solutions such as Calma's GDS II could.

In early 1984 the company announced the Apollo-based TEGAStation that incorporated software it had acquired the prior year from Communications Satellite Corporation. Both Apollo DN300 and the DN420 systems were offered. TEGAStation consisted of over a dozen application packages for schematic capture, simulation, test and analysis at prices ranging from $25,000 to $90,000. The company also introduced a new printed circuit board package called T-BOARDS. Unfortunately, it eventually proved to be too little too late. The GDS II system, which was the heart of the company's electronics product line, was available just on Data General computers and that platform was rapidly falling out of favor with high tech users who preferred the new generation of UNIX workstations from companies such as Apollo and Sun Microsystems.

In addition to the problem of platform inconsistency, Calma had to overcome the fact that its primary competitors in the electronics market were no longer the traditional turnkey CAD systems manufacturers such as Computervision and Applicon. The new competition was companies such as Mentor Graphics and Cadence that had two advantages – they were pure software plays and did not have the need to support an expensive hardware design and manufacturing infrastructure and this was the only market they were interested in.

The latter factor cannot be over-emphasized. At Calma, as was the case at other companies pursuing multiple markets, there typically was a constant debate over which market to allocate resources to, whether for product development or sales and marketing. At Mentor Graphics and Cadence, there was no such debate – the resources were directed at the needs of the electronics market without question. It is interesting to note that when these companies were first launched, their software packages did not handle the physical layout of integrated circuits. Rather, they produced input for Calma's GDS II software which continued to handle those functions for many users.

By 1986 GDS II and related applications were finally available on Digital VAX systems in addition to the Data General computers which had been supported since the early 1970s. The 32-bit version was referred to as GDS II/32. See Figure 11.5. One of the more interesting hardware components offered by the company was an optional attached processor called the Fast Mask Engine or FME. This unit was designed to handle specific design tasks such as design rule checking and integrated circuit mask resizing. The FME was developed by Silicon Solution Corporation of Menlo Park, California working on an exclusive agreement with Calma. The basic FME hardware started out in May 1984 with just 750 KB of memory and a 80 MB disk. It was subsequently upgraded to a system consisting of a Motorola 68010 microprocessor, 125 MB of main memory and a 160 MB disk drive. The FME could exchange data with a GDS II system either through an on-line direct link or off-line using magnetic tape as the exchange medium.

In September 1985 a new subsystem was added to the FME that used multiple 68020 microprocessors that further reduced the time it took to do complex integrated circuit analyses. In mid-1986 an updated version of this device was introduced that communicated with a GDS II/32 system via an Ethernet connection. The FME performed design and electrical rule checking five to ten times faster than a dedicated VAX 11/780. It also was able to handle plotting about four times faster.[24]

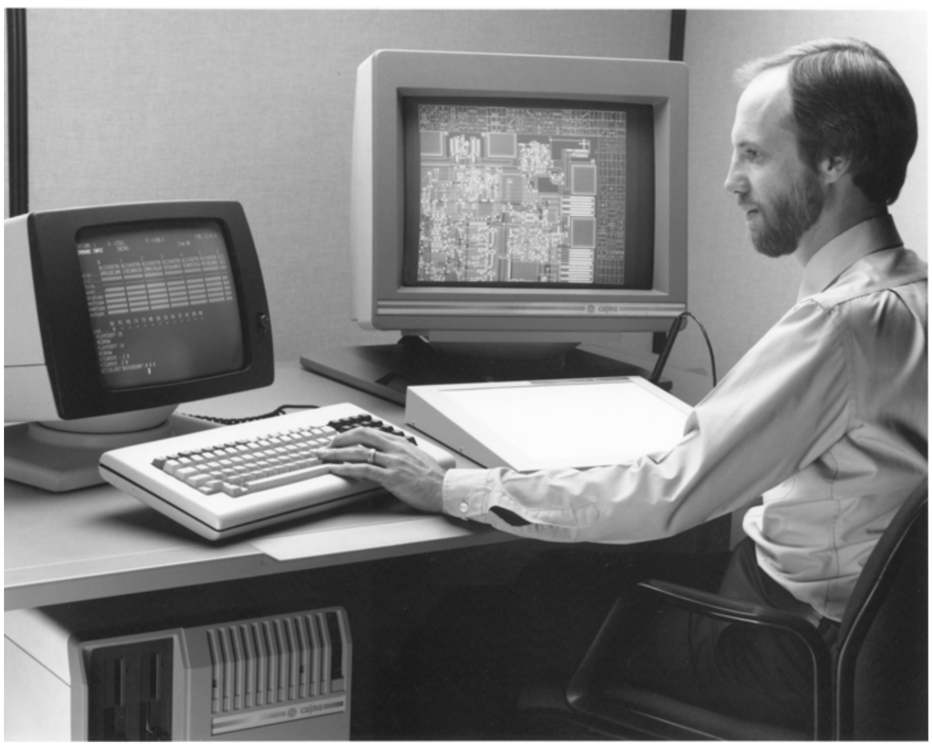

Figure 11.5
GDS II/32 System

Calma also expanded the use of Apollo workstations to support its electronic software. In addition to TEGAStation, the company introduced the BOARD Series of printed circuit board engineering and design products in July 1986. There were three packages in this series: BOARD Designer, BOARD Editor Plus and BOARD Expeditor. BOARD Designer was a comprehensive schematic capture, placement, routing and

[24] Calma press release, July 31, 1986

manufacturing output solution while BOARD Editor Plus provided the same capabilities less the routing and manufacturing output. The latter package was specifically intended to be used on low-cost workstations such as the Apollo DN3000C. BOARD Expeditor was a high-performance routing node for handling large complex boards. The BOARD Series was also supported on the Apollo DN660.

Figure 11.6
Calma BOARDS Series Running on Apollo DN3000

As the semiconductor design industry was moving away from manual circuit layout to more automated techniques, GE's R&D Center in Schenectady, NY developed an advanced silicon compiler. At an IEEE Solid State Circuits Conference in February 1987, Dr. Sharbel Noujaim described how this software was used to design two CMOS devices in three working days. One device contained 35,000 transistors while the other contained 15,000. GE claimed that other software techniques would have taken six to eight months and manual procedures a year. It is not clear if this software was ever commercialized by Calma.

**Calma's mechanical products mature**

Although Calma was not taking the mechanical market by storm, sales of its DDM software were slowly edging up. By 1985 this sector represented over $100 million in revenue for the company although it is not clear how much of this business represented the resale of SDRC solids modeling and analysis software. DDM software was being supported on DEC VAX and MicroVAX hardware as well as on Apollo workstations. Prices ranged from about $58,000 to $90,000 per seat. A MicroVAX II implementation of DDM was introduced in October 1985 with a two-seat configuration selling for under $150,000. These systems included a new graphics terminal, the GPS100. At the same time, SDRC's I-DEAS and Calma's Dimension III were made available on this platform.

Calma also introduced a PC/AT system capable of handling two-dimensional drafting tasks in October 1985. Called DraftStation, it could extract model data from larger DDM systems and handle drafting-type tasks. The software was developed for Calma by IBM's Boulder, Colorado laboratory, the same group that developed IBM's FastDraft product. DraftStation cost $27,450 for a complete hardware and software configuration.

The hardware consisted of an Intel 80286 PC/AT with 512KB of memory, a math co-processor, a 20MB disk, a high-resolution (1024 by 1024) 19-inch display, a 32-bit graphics processor and a tablet. Other IBM-compatible peripherals could be added as well as Hewlett-Packard 7000 Series plotters. The DOS 3.1-based software contained a fairly comprehensive set of drafting functions including the ability to execute Boolean operations on geometric entities and import text such as a bill-of-material information from a word processing system.

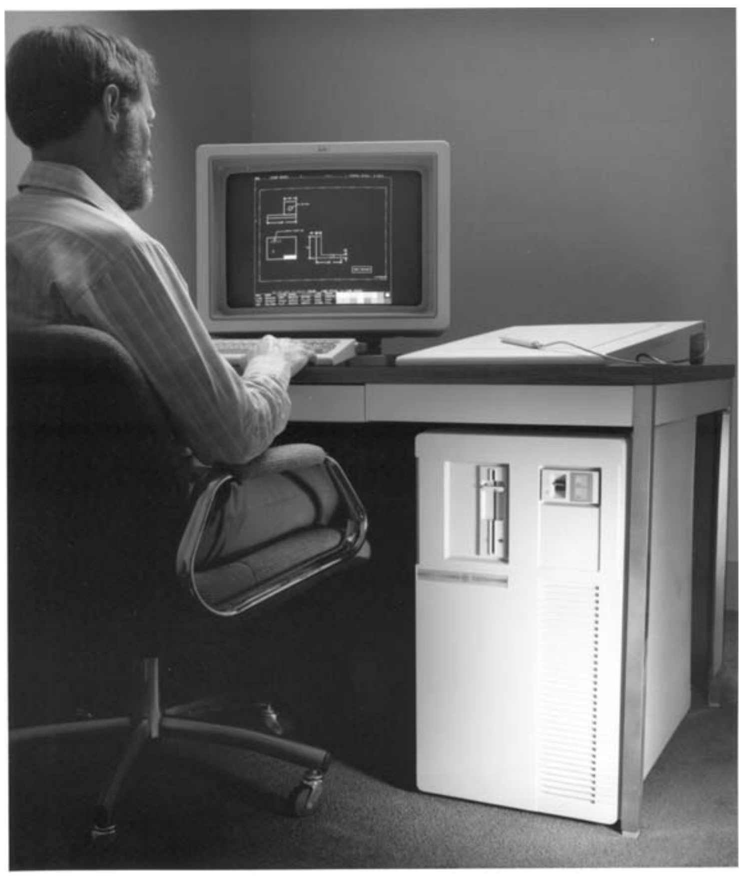

Figure 11.7
PC/AT-Based DraftStation

It is not clear why this system was promoted predominately as a mechanical drafting system and not as a low-cost AEC or electrical schematic design system also.

Calma pushed the idea that the DraftStation software could be learned in as little as a week and that formal classes were not necessary. In addition to Calma's own sales force, DraftStation was sold by General Electric Supply Company's (GESCO) 700-person sales force. Although it appears to have had greater functionality than Autodesk's AutoCAD had at the time, it also cost more than twice as much for a complete system. Calma realized this disparity fairly quickly and about six months after DraftStation began shipping it reduced the system price for a new higher speed configuration to $21,950. The new system used PCs with Intel's new 8-MHz processor rather than the 6-MHz device used initially.

Around the same time, Calma published a report that compared manual drafting with a popular software package (presumed to be AutoCAD) and DraftStation. The report showed that in the hands of an experienced user, DraftStation was about four times as productive as manual drafting and about three times as productive as an advanced AutoCAD user. Calma also claimed that DraftStation required much less training. Whether or not these statistics were accurate, the less expensive AutoCAD product still significantly outsold DraftStation.

Figure 11.8
Dimension III Running on Apollo DN3000

The surprise at the time was probably the company's AEC business which represented close to $30 million in revenue in 1985. Dimension III was available on the same platforms as DDM and was priced comparably.[25] In June 1986, the Dimension III software was ported to the Apollo DN3000 workstation. Because the software had originally been developed for Calma's dual screen workstations, a secondary alphanumeric terminal was needed to run this software on the DN3000 as shown in Figure 11.8. Towards the end of 1986, Calma won a $19.5 million order from the U.S.

[25] *The Anderson Report*, February 1986, pg. 3

 

Bureau of Reclamation in Denver for 51 MicroVAX systems supporting 95 workstations. This probably represented the high point of the company's AEC business.

Other GE divisions continued to target the graphics market. One example was the company's Silicon Systems Technology Department in Research Triangle Park, North Carolina. In May 1986 it introduced the Graphicon 700, a high-performance three-dimension graphics processor that performed over 30 million floating point operations per second. It could render about 13,000 polygons per second using a 1280 by 1024 display with a 16-bit Z buffer and up to 16 MB of local memory. The Graphicon 700 was priced at $65,900 without a CRT monitor or about $33,000 in quantities of 100.

**Calma Launches New Version of DDM**

In September 1986 Calma introduced a new version of DDM called the Prism/DDM system. This was essentially version 3.0 of DDM. The most significant enhancement was the incorporation of a CSG (Constructive Solid Geometry) solids modeler in the basic Prism/DDM software. Once a model was completed the software created a boundary representation of the data from which surface and wireframe versions could be derived. This information, along with various types of attribute data was stored in a double precision database. The incorporation of basic solids modeling capabilities in Calma's own product was not intended to negate the companies previously established relationship with SDRC for integration of the latter company's design and analysis software with DDM. Prism/DDM also sported a new user interface that utilized a combination of new on-screen menus together with prior user interface features.

The new solids capability was incorporated into Prism/DDM's NC capabilities. The software's Interactive Tool Path module enabled a user to define tool paths, feed speeds, etc. and see the results of these decisions on the machining of the part. The software simulated tool movements using a color visualization representation of the solid model with the removed material highlighted. The intent was provide tools that would enable the NC programmer to optimize the NC operation while avoiding problems such as gouges, differences from the original model and collisions with tooling fixtures.

The machining visualization software was developed at GE's R&D Center in Schenectady, NY by Dr. Weiping Wang. Initially, the software was only available on systems using the Graphicon 700 terminal. It was early 1988 before the package was available on standard Apollo and DEC workstations.[26] The same GE organization also developed a sheet metal verification program called SHEETS.

Prism/DDM was offered on the same VAX and Apollo platforms as was the earlier version of DDM with the exception that the MicroVAX II version supported GE's new Graphicon 700 display system. The list price for the software was $29,000 per seat. A three seat Prism/DDM system using a MicroVAX II and conventional Calma graphics terminals sold for $69,000 per seat while the same configuration with the Graphicon 700 sold for $91,500 per seat. Apollo based systems sold for $51,800 to $78,500 per seat.

**Treading water and then sale to Valid and Prime**

After the launch of Prism/DDM, Calma went about trying to establish some market momentum without much success. In March 1987 the company laid off 25 people at its San Diego research facility while at the same time hiring more sales people. The

[26] Calma press release, March 31, 1988

 

company stated that it was cutting back on internal hardware development since it planned to increasingly depend on GE's Silicon Systems Division for that technology. The company also killed a database management project code named "Genus" with the comment that it would use DBMS products from other sources.[27] In May of that year the company introduced a "project walk through" software package for the Dimension III AEC market utilizing the Graphicon 700 display. This application was priced at $50,000 for both the display hardware and the walk through software.

In August 1987 Calma segmented its Prism/DDM software into seven functional modules with prices ranging from $2,500 to $10,000 per module. The seven modules were Prism/Draft, 3-D Modeling, Surfacing, Sub Modeling, DAL, DAL/Fortran, and Hidden Line. The entire suite sold for $27,900. An Apollo DN3000 system with just drafting software was priced under $25,500 as compared to the company's previous starting price of $56,000. The objective was to be able to compete more effectively with other companies that were unbundling their software. Similar unbundled prices were also established for Dimension III software.

By late 1987 it was becoming obvious that Calma was unlikely to become a dominating player in the CAD/CAM industry. Employee headcount had dropped to 900 and revenue was down to $180 million in 1987. The company lost about $26 million in 1986 and $20 million in 1987 according to *The Anderson Report*.[28] While Calma was making some progress with its mechanical and AEC product lines, its electronics business was under tremendous pressure from Daisy, Mentor Graphics and Valid Logic.

The Data General-based GDS II software might have had a cult-like following within the semiconductor industry, but fewer and fewer IC products were being designed using the techniques implemented in this system. The company still claimed that as of late 1987, over 70 percent of all integrated circuits ever developed had been designed using GDS II technology. That was probably accurate but totally irrelevant considering how fast design technology was changing.

On September 15, 1987 Calma announced EDS III which was an extension of its older GDS II/32 integrated circuit physical layout software. A key aspect of this announcement was the fact that the package, written in the C programming language, was to be available on Sun, Apollo and DEC workstations. Sun was rapidly becoming the preferred design platform in the electronics industry and although Calma utilized over 40 Sun workstations internally for software development this was the first software product the company offered on that platform.

As well as selling turnkey EDS III systems, Calma planned to sell this software unbundled. The EDS III system incorporated new design management tools that could access legacy GDS II data files. Calma began shipping EDS III in January 1988 but customer acceptance was slow to get off the ground. The electronics sector, under senior vice president Bruce Gregory, now represented just 25 percent of Calma's business or about the same portion as its Dimension III AEC business.

On top of its faltering electronics business, Calma was also in the midst of making the transition from being a graphics hardware manufacturer to a software business. Every company that went through the same transition had tremendous difficulties – financial, sales, marketing, engineering and personnel management. Calma was no exception – it

[27] *Computer Aided Design Report*, March 1987, Pg. 10
[28] *The Anderson Report*, march 1988, Pg. 3

 

just happened to hit the wall earlier than Applicon, Auto-trol, Computervision or Intergraph. By March 1988, rumors were starting to swirl that GE might be ready sell the company. According to McGlaughlin, “The company is taking a proactive role in looking for synergistic relationships.”[29]

In April 1988, GE began breaking up Calma. It sold the electronics portion of the company’s product line, which had about $40 million in annual revenues in 1987 and about 2,700 users, to Valid Logic. By comparison, Valid had revenues of $67 million in 1987 and over 4,500 users. After reviewing the company’s financial statements, industry analysts concluded that Valid had paid only about $3 million for Calma’s electronic design product line.[30]

The party line was that Calma would now focus on just the mechanical and AEC markets. That position didn’t last very long. On October 18, 1988, GE announced that it was selling what was left of Calma to Prime Computer which had acquired Computervision earlier in 1988. While Calma had done about $90 million in mechanical CAD business in 1987, its 1988 revenue in this area had plunged to no more than $50 million according to Daratech’s Charles Foundyller. Based upon the analysis of the Valid deal, Prime probably did not pay very much for what was left of Calma. When GE wanted out of something, it just wanted out.

As part of the deal, Prime became a preferred vendor within GE. The actual sale was consummated in January 1989. Little work subsequently went into enhancing Prism/DDM and its related applications and over the next several years customers either switched to Computervision’s CADDS software or Medusa or changed vendors and went with competitors including Parametric Technology Corporation, McAuto or Applicon.

Dimension III, on the other hand, seemed to have nine lives. It survived the Prime acquisition, the eventual resurrection of Computervision and even PTC’s acquisition of Computervision. Although it was not enhanced to any significant extent, Dimension III stayed in use at a number of customer sites such as Ingalls Shipbuilding well into the late 1990s.

After the Prime acquisition of what was left of Calma, McGlaughlin went to work for Equifax, initially to head up their IT activity. He eventually became president and CEO in 1996 and held that position until January 1998.

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[29] *The Anderson Report*, March 1988, pg. 3
[30] *Computer Aided Design Report*, November 1988, Pg. 9

# Chapter 12

# Computervision

According to a 1994 *Wall Street Journal* article, Philippe Villers decided to start a technology company shortly after listening to the minister at Concord, Massachusetts' First Parish Church extol Martin Luther King's accomplishments a few days after he was murdered in April 1968. Villers felt he needed to do something meaningful with his life and that there were two options – either become a social activist or start a company, make a lot of money and then use that money to change the world. Luckily for what eventually became the CAD/CAM industry, he chose the second path.[1]

Villers was technically well qualified to start Computervision, Inc. or CV is it was generally known. Born in Paris, France, he came to this country via Canada in the early 1940s to escape the Nazis. Villers had an undergraduate liberal arts degree from Harvard and a masters degree in mechanical engineering from MIT. He worked for several years in General Electric's management training program followed by stints at Perkin Elmer, Barnes Engineering and the Link Division of Singer-General Precision with increasing levels of project management responsibility. At the time he decided to establish Computervision, Villers was Manager of Advanced Products at Concord Control in Boston.

Villers spent much of his spare time in 1968 meeting with a group of business and technical associates including Steve Coons and Nicholas Negroponte (founder of the MIT Media Lab). Realizing that it takes more than good technical ideas to build a successful company, Villers decided to find a partner with more business experience to help jump start the enterprise. Martin Allen, who had been Villers boss at Link was a natural choice for this role. Allen was a mechanical engineer from the University of California who had previously worked for TRW, Martin-Marietta in addition to Singer-General Precision. The plan was for Allen to be the company's president while Villers would be senior vice president.

For the first few months in early 1969 while the company was in the process of obtaining its initial outside funding, Villers was the president of the company. At that point Computervision was being funded by Villers' friends and relatives. Eventually, the company was able to raise about a million dollars from a small New York venture capital fund called the Targa Fund, partners at Paine Webber Jackson and Curtis and the Diebold Group. At that point Allen joined the company as president and Villers switched to senior vice president as the two had previously agreed. Another of the company's early venture capital backers was Ampersand Ventures which made a significant financial commitment in 1970. By coincidence, that firm also was one of the initial backers of Prime Computer in 1972. Little did they know at the time how these two companies would end up on a collision course in the late 1980s.

For the next decade the relationship between the two founders appears to have been a very workable arrangement. As the company's senior vice president Villers was the person most responsible for driving Computervision's product development strategy. While Allen would stay with the company as either CEO or chairman until the late 1980s,

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[1] Wartzman, Rick, *Wall Street Journal*, June 1, 1994

Villers left in 1980 as discussed later to form first Automatix, Inc., a robotics and machine vision company, and subsequently Cognition, Inc., a mechanical CAE firm.

**CV's early product strategy**

The original Computervision product strategy involved designing and producing several hardware products in order to generate revenue while the company created the initial release of its CADDS (Computer-Aided Design and Drafting System) software. Three people were recruited to head up hardware development: David Friedman was responsible for the Interact terminal, Joe Sliwkowski the Compucircuit photoplotter and Ken Levy the Autolign semiconductor mask aligner. The first two programmers hired to develop the CADDS software were Robert Blauth and Bert Bruce. Blauth would eventually take on responsibility for all the company's research and development.

Villers technical specialty was the design of high precision electro-mechanical devices. In the 1969 time frame, the electronics industry was entering its first surge of significant growth powered by new integrated circuit technology. One of the major problems facing the semiconductor industry was producing the masks that were used to manufacture the silicon wafers that each contained multiple copies of the circuit being produced. Using a technology called "photolithography" an integrated circuit is made of multiple layers of material and each layer required one or more masks which had to be precisely aligned with the others.

While today's 12-inch wafers contain literally hundreds if not thousands of individual circuits in 1969 a 4-inch wafer might have contained a few dozen at most. But the technology available four decades ago was much cruder than what we have today and there was the need for devices that could quickly and accurately align individual circuit artwork to produce mask sets. The manual methods that were then available were slow and susceptible to error. At the time, this work had to done to the precision of a micron and operators worked with high-powered microscopes to align the masks.

Villers designed the Autolign automatic mask aligner for the semiconductor industry with the expectation that it would be the company's "bread and butter" product until its engineering design and drafting products were ready for market. For the company's first several years this proved to be the case as revenue was dominated by Autolign products. Computervision produced the Autolign product by purchasing manual aligners from Kulicke & Soffa and adding its own electronics and drive mechanisms.

The Compucircuit, on the other hand, was designed from the ground up by Computervision engineers. Prior to the advent of computer-based systems, printed circuit boards (PCBs) were produced by either manually drafting the board's circuit traces and pads using stick-on tape on sheets of mylar or plotted on Rubylith peelcoat material using a sharp knife mounted on the plotter head. Typically these layouts were twice or four times the size of the actual board. Each layer of the circuit board required a separate artwork sheet. These circuits layouts were then photo reduced to actual size and used to manufacture the circuit boards. Other than the scale and precision of the artwork, it was quite similar to the way integrated circuits were produced. The Compucircuit plotted the printed circuit layout directly on film at the same scale needed for production, eliminating the photo reduction step. It was both faster and more accurate than the earlier procedures used to produce PCB artwork.

 

The third hardware product, the INTERACT, was intended from the start to be a key element of the company’s CAD/CAM solution. This device was a combination of a digitizer and a plotter and was the company’s only interactive terminal. Villers describes it a “Large Interactive Surface” that shared the electronics of a storage tube-based terminal. The operator could copy a sketched part, view it on a CRT screen, make editing changes and plot the results. The first Interact was shipped in 1970 to Sperry Gyroscope. Eventually this system was returned to Computervision where it was displayed in the company’s lobby for a number of years. Computervision claimed that this particular unit had 28,000 operating hours with just 3% downtime. Various version of the INTERACT were manufactured until around 1980.

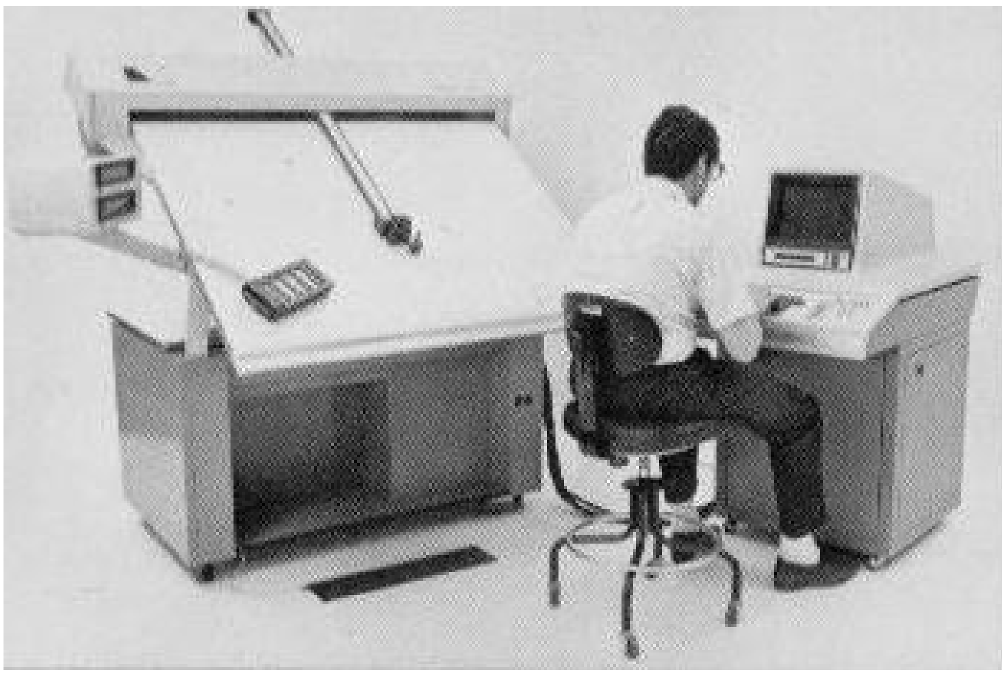

Figure 12.1
Early Computervision Interact Terminal

The initial Computervision product strategy was to operate the Interact terminal with software running on a time-sharing system. The Compucircuit photoplotter was intended to operate with data generated on-line using a remote computer system or with data stored on magnetic tape. The time-sharing concept proved to be impractical due to the slow 300 baud communication speeds then available and the unreliability of computer utilities. About a year after the company started, the plan changed and Computervision began using the new Nova 16-bit minicomputer from Data General.

**Off to a fast start**

Computervision was one of the dominating companies in the CAD industry throughout the 1970s and most of the 1980s, at one time having a 35% to 40% market share. Several developments had come together by 1970 to make the commercial CAD systems business a viable endeavor. Minicomputers from companies such as Data General, Digital Equipment and Scientific Data Systems were being sold at manageable prices, low-cost storage tube display terminals were commercially available or companies could build their own terminals with storage tube displays procured from Tektronix, digital plotters were available from CalComp and several other firms and many of the fundamental software concepts for two-dimensional and three-dimensional graphics had been published in technical proceedings. The basic technology pieces were in place. The major task was to develop reliable software that would do enough of the design and drafting task so as to be accepted by the user community.

The company got off to a quick start by focusing on what can best be described as production drafting. Early systems were particularly well tuned to the needs of drafters as exemplified by the company's INTERACT workstation. Although both Allen and Villers had mechanical engineering backgrounds, the early Computervision systems were targeted at electronics users, especially companies that wanted to automate the production of printed circuit board artwork. Technically, the process for preparing this artwork on a computer was a relatively straightforward two-dimensional task, particularly as compared to subsequent activity related to three-dimensional mechanical design. There was also the need to produce a variety of non-scaled schematic drawings documenting the logic of the PCBs.

The Computervision CADDS system was both a radical departure from traditional practice but still a process that drafters could identify with, particularly with the use of the INTERACT workstation. PCB artwork generation and schematic documentation typically involved placing a substantial amount of duplicate graphical entities such as the mounting hole pattern for an integrated circuit on a PCB layout or the symbol for a transistor on a schematic diagram. Even early CAD systems proved to be extremely productive when working with duplicative symbology. Computervision's CADDS system was quite effective when used for these tasks. Once a PCB layout was created using the computer, photographic quality copies could be generated by outputting the information to a Compucircuit photoplotter. This device created the artwork on a sheet of photographic film by exposing apertures describing each type of connection pad or line trace. The film was then developed and used in the same manner from that step on as film produced from photographing manually taped artwork.

Most of the first 200 Computervision systems sold were used for PCB artwork generation. Integrated circuit artwork generation was similar in many respects to PCB drafting in the early 1970s. IC artwork was typically produced on large sheets of grid paper with the different layers of the circuit shown in different colors. These drawings were then used as the basis for producing detailed large-scale artwork master on a material called peelcoat. This process involved cutting through the top layer of the material and then carefully removing the material representing the circuit layer in question. From that point on the process was similar to PCB artwork where the sheets were photographically reduced to be used as production masters except that the IC people referred to producing this final artwork as "mask making."

Two trends were driving semiconductor companies to automate the IC mask making process in the early 1970s. First, integrated circuits were becoming far more complex. This was about the time that Intel's Gordon Moore declared that integrated circuit density was doubling every 18 months – a trend now known as Moore's Law. Design and production personnel could see a time when it would become almost impossible to continue using manual artwork creation procedures due to the growing complexity of circuits. The second issue was perhaps even more important. The mask making process was switching from traditional photographic reduction techniques to the use of new devices that were driven by digital data. Companies had to produce a digital record of the circuit layout in order to drive these machines.

Computervision saw the IC market for their CADDS systems as a logical extension of the PCB electronics market and the company added semiconductor mask making capabilities to its software. While Computervision dominated the market for PCB artwork and schematic drafting, in the early 1970s, Calma similarly dominated the IC market. The two companies frequently competed in both areas of the overall electronic market with Computervision typically winning the larger PCB business while Calma, as described earlier, winning a majority of the IC business. The Autolign products were typically sold independently of the company's CADDS systems.

**Personnel and organization**

During Computervision's first decade Villers was responsible for most of the company's internal operations, especially those related to product development while Allen handled external activities. Both were typically involved in presentations to potential investors. Even though Villers was responsible for the initial idea to establish a company to manufacturer the hardware and software products described above, he seems to have had few problems actually reporting to Allen. This may well have been a result of the fact that Villers had worked for Allen earlier at Link.

Over the years, Computervision was particularly successful in recruiting an excellent team of technical and business managers including Phil Reed and Ken Versprille. Villers was personally instrumental in bringing Sam Geisberg, a brilliant Russian mathematician who would later start Parametric Technology Corporation, to the United States in 1974 to work for Computervision. Sam's brother Vladimir initially immigrated to Israel but subsequently moved to the United States and also joined Computervision.

Computervision went public the first time in December 1972 and was listed on the New Stock Exchange under the CVN ticker symbol in 1979.

**Computervision becomes a computer manufacturer**

Rarely when analyzing a company's history is it possible to point to a single event or decision and claim that it was the determining turning point in the enterprise's future. Computervision's decision to build it own computer systems may well have been such an event. For the first few years it had used Nova computers purchased from Data General. These were relatively inexpensive machines but Computervision believed that it could both increase its profit margins and produce a computer better tuned to the needs of its customers by building its own machines.

A west coast company had reverse engineered the Data General Nova computer and produced a chip set that enabled companies such as Computervision to manufacture similar machines at a far lower cost than what they were paying Data General. Villers saw this as a low risk strategy compared to the company designing its own computer which apparently was an option being considered. Around 1978 the company began manufacturing a computer called the CGP-100 where CGP stood for Computervision Graphics Processor. This led to the construction of several large manufacturing facilities along with the installation of machinery and equipment for building and testing these machines. Needless to say, Data General was not happy about this development and tried to get Computervision to consider new machines it was working on by offering attractive business terms. As different from what would probably happen today, there does not appear to have been any lawsuits over misappropriated intellectual property.

The CGP-100 was designed by a group of computer design engineers who were referred to as "Computer Gypsies" because they tended to move from company to company in the Boston area designing minicomputers as they went. They apparently did a good job because it was difficult for Computervision's programmers to tell the difference between a Data General Nova and the CGP-100. This new machine was a 16-bit minicomputer with a memory that was expandable to 512K words. It supported a 14 million word disk drive and other standard peripheral devices such as magnetic tape drives. As mentioned earlier, Computervision terminals utilized Tektronix storage tube displays. The company was quick in moving to the 19-inch versions once they became available in the mid-1970s. These terminals used a 11-inch by 11-inch tablet or a large free-standing digitizer for user interaction as well as the previously described INTERACT plot-back digitizer.

In 1978 a base CGP-100 system with a 512-word memory sold for $140,000 while interactive terminals went for $40,000 to $65,000. The three-dimensional mechanical design and drafting software described below cost $10,000 while NC software was another $5,000. With this pricing structure one could conclude that in the 1978 timeframe, Computervision was primarily a computer equipment manufacturing company that happened to also sell CAD software.

**Cobilt expands CV's manufacturing**

Computervision acquired Cobilt, a manufacturing of integrated circuit mask making equipment, in 1971. Cobilt was founded in 1970 by Peter Wolken, Gerd Schlieman, Allan Fleming and Fred Schultz. This acquisition was intended to both increase the company's manufacturing capabilities in a rapidly growing market as well as enable Computervision to sell more comprehensive systems into the semiconductor industry. Kenneth Levy, who was responsible for Computervision's Autolign product, was initially put in charge of the Cobilt division. By 1977, with Sam Harrell running the division, it was generating $18.2 million in annual revenues, nearly 40% of the company's total.

Levy left Cobilt in 1975 and founded KLA Instruments (today KLA-Tencor, a major manufacturer of semiconductor production equipment) where he was CEO until 1999 and chairman of the board until 2006. Wolken and Harrell both eventually joined Levy at KLA.

Although revenues increased rapidly, Cobilt was never particularly profitable and around 1980 Computervision began selling it off piecemeal. Most of Cobilt was eventually sold to Applied Materials in 1981 for $14 million. Computervision was plagued with lawsuits resulting from its ownership of Cobilt and it would take until 1984 to settle them all. The company reported a $10 million loss that year attributed to putting the last of the Cobilt claims behind it.

While manufacturing photoplotter and semiconductor mask making equipment was important, it did not go to the heart of the company's business the way building its own computers did. Not only did designing and producing these computers require the company to establish a substantial production capability but it also required that it assume responsibility for the computer's operating system and software development tools. And it had to do so without the ability to spread those costs over the much larger number of machines sold by primary computer manufacturers such as Digital Equipment and Data General.

Computervision got into the hardware manufacturing business at a time when minicomputers were rather straightforward machines. Within a few years, the technology became far more complicated and when the company attempted to make the transition from 16-bit to 32-bit computers, the economics of the situation started working against it. Extracting itself from the computer manufacturing business eventually damaged the company's finances to the point that Computervision became the target for a hostile takeover by Prime Computer as described below.

**New software broadens Computervision's mechanical capabilities**

For the first few years, Computervision focused almost entirely on electrical design applications such as the layout of printed circuit boards. While the initial CADDS software was capable of doing mechanical drafting, it did not have the three-dimensional modeling capabilities that customers were starting to ask for. In the process of competing for business at Boeing, Computervision ran into competition from a small software firm in San Diego, California called System Science and Software – more frequently referred to as $S^3$.

While most of this company's business activity was focused on scientific and technical projects for federal government agencies, it had acquired a CAD software company called Integrated Computer Systems. Started by Patrick Hanratty, ICS had developed a package called INTERAPT. As described in Chapter 15, the acquisition of ICS led to a lawsuit against Hanratty who did not stay with the company after it was acquired by $S^3$.

The CAD software business unit at $S^3$ was struggling at the time and when Computervision offered to buy that operation, the deal was executed fairly quickly. As part of buying this business activity from $S^3$, Computervision inherited the lawsuit against Hanratty which was still pending. Dave Albert who was heading this operation, Jerry Devere who had helped start ICS and about ten others moved to a new office facility in Rose Canyon, north of San Diego, and began working on porting $S^3$'s INTERAPT software to the Data General computers Computervision was using at the time.

Albert remembers the relationship with Computervision getting off to a fairly rocky start. Phil Villers visited the new office shortly after they had moved in and made it clear that he had opposed the acquisition and wanted to close the office. Meanwhile, the company settled the lawsuit with Hanratty by licensing his then current ADAM package and paying him a monthly retainer for about a year.

 

The new mechanical design and drafting software, now known as CADDS 3, was introduced in 1973. Most of the work was done in California although some user interface functions were developed at Computervision's headquarters in Bedford. For the next several years, the San Diego and Bedford programming groups worked together on enhancing CADDS 3.

Towards the end of 1975, Computervision decided that it wanted to consolidate its CADDS programming activity in Bedford and offered the San Diego staff new positions in Massachusetts. By now there were about 30 people in the Rose Canyon office. While some people accepted the offer to move back east, most did not. Under Albert's leadership, they stated to form a new software company. Before that idea had proceeded very far, the team decided to join Calma and stay in southern California. Computervision was not happy about them joining a competitor but, contrary to some misconceptions, never sued Calma over hiring Albert and other core members of the San Diego team.

Indicative of how small a world this really is, Albert was vacationing in New Zealand in the spring of 2003 and stayed at the local equivalent of a small bed & breakfast. Upon leaving he went to sign the guest book and found the Villers had been there about a month earlier.[2]

**Computer becomes dominating force in CAD industry**

In May 1975 Computervision hired Ken Versprille[3] soon after he received his Ph.D. from Syracuse University. While at Syracuse Versprille worked closely with Steve Coons, the developer of the Coons Patch used for defining surface geometry. As described in Chapter 2, Versprille's Ph.D. thesis involved the development of a more advanced technique for defining surfaces known throughout the computer graphics industry as NURBS or Non-Uniform Rational B-Splines.

Computervision's growth had been fairly rapid in the early 1970s and by 1974 the company's annual revenues were over $25 million and the business was nicely profitable. 1975 saw the United States in the midst of a recession and sales dropped to $21 million and the company incurred a $4 million loss. At this point, there were two schools of though within Computervision's management. One group felt that the company should hunker down, reduce expenses as much as possible and wait out the recession. The other group, led by Mike Cronin, lobbied for increasing research and development as well as expanding sales so that when the recession ended, Computervision would have the strongest product portfolio in the nascent CAD industry and would be able to grow faster than its competitors. This latter approach won out and Versprille along with perhaps 20 other programmers were hired. It proved to be the correct strategy in that Computervision sales increased rapidly in the late 1970s and by 1980 the company's annual revenues were nearly $225.

Hired as a senior programmer, Versprille's initial assignment was to make the CADDS 3 software more three-dimensionally oriented. The first versions of the package required defining geometry on two-dimensional planes which were then projected into

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[2] David Albert interview September 19, 2003

[3] Various reference to Ken Versprille are based on a series of telephone interviews with the author during July and August 2003

 

three dimensions. This was about a year-long project which was followed by a similar task to improve the geometric creation of three-dimension splines.

Another project around this same time involved changing the graphics display routines from integer arithmetic to floating point. An integer method had been used by the San Diego development group to maximize graphics performance except that it failed when model values exceeded predefined limits. In Bedford, they redid these routines using a normalized floating point technique that enabled models to span greater dimensions while sacrificing little in regards to performance. The new software enabled the Computervision programmers to create a technique they called “bounding boxes.” These defined the minimum and maximum values that could be expected for the part being designed. The result was that images could be scaled by a factor of two by using extremely fast shifting operations. One problem with this technique was that these minimum and maximum values had to be defined when the design of the part was initiated.

Versprille points out that the programming staff in Bedford was relatively small and that everyone had to do everything. This resulted in a group of developers who were broadly familiar with full range of the company’s software products. As Computervision grew, new hires tended to be given assignments that had them focusing on narrow segments of the software. One result was that early employees tended to end up in staff positions where their responsibilities encompassed broad segments of the company’s product line.

**Computervision in the late 1970s**

In 1978, Computervision was still being run by Martin Allen as president and CEO while Phil Villers was a senior vice president in charge of long term strategic planning. Michael Cronin had responsibility for several marketing and R&D activities, Sam Harrell was running the Cobilt operation, Dave Friedman was vice president of engineering and Bob Gothie was vice president of marketing. Field sales in the United States was headed up by Ralph Shubert who reported to Gothie. By the late 1970s the company’s focus had switched from electronic design to mechanical applications with a moderate amount of activity in the AEC field.

Sales were handled by a direct sales force in the United States and much of Western Europe while distributors were utilized in Japan and other countries. The typical system sold for between $250,000 and $400,000 and the company had an installed base of approximately 500 systems. Major customers included General Electric (45 systems), Ford Motor Company (10 systems), General Motors, Boeing, Pratt & Whitney and McDonnell Douglas. Overall, sales were increasing fairly rapidly except for the previously mentioned dip in 1975. Revenues in 1978 were nearly $72 million. By this point the company’s software development staff consisted of about 120 individuals.

The primary computer system was the company’s own CGP-100 described early along with terminals utilizing Tektronix storage tube displays. The basic two-dimensional software used for electrical applications such as PCB layout was now known as CADDS 2 while the three-dimensional mechanical software was referred to as CADDS 3. Among the important features contained in CADDS 3 were:

- Both two-dimensional or three-dimensional design modes.
- Cross sections of three-dimension parts.

 

- B-spline curves and surfaces.
- Concept of parts and sub-parts.
- Finite element mesh generation based on GIFTS (developed at the University of Arizona).
- Drafting with automatic dimensions, tolerances, labels and notes.
- Isometric views.
- Interactive generation and editing of NC tool paths.
- User development language called Parametric Element Processor (PEP).
- Data communication with mainframe computers.

**Life After Computervision**

Phil Villers left Computervision in January 1981 after the company rejected two new venture proposals he had made. The first was for a low-cost system that would combine a computer and terminal into a single integrated system. This concept was similar to the engineering workstation being developed at the time by Apollo Computer and several other companies. Villers believes that the failure to do so was one of the major factors that eventually led to Computervision's decline in the CAD/CAM industry.[4] Earlier, in the summer of 1980, Villers had made a proposal for the company to expand into robotics and artificial vision systems for manufacturing companies.

Upon leaving Computervision, Villers started Automatix, a company focused on robotics and artificial vision. (Actually, the company may have been stated somewhat earlier in 1980.) He was president until 1984 and then chairman of the board until 1986. In 1985 he founded Cognition, a software company that developed and marketed mechanical engineering design software that could be used by engineers, especially during the concept design phase of a project. He remained president of that company until 1988. As this is being written, its president and CEO is Mike Cronin who was in charge of sales for Computervision throughout most of the 1970s.

When Villers left Computervision in 1981 he was worth over $80 million. Having met the goal he set for himself in 1968 he decided to do something significant with this money. He and his wife Katherine took half that money and established the Villers Foundation. Known today as Families USA Foundation, it has been active in lobbying the federal government to provide better healthcare for the nation. In 1994, when the Clinton administration was engaged in trying to develop a universal health plan, Villers and Families USA were in the middle of trying to develop support for the plan. This activity was of sufficient visibility that the *Wall Street Journal* ran a feature article on the foundation and Villers in its June 1, 1994 issue.[5]

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[4] Personal communication with Philippe Villers October 22, 2003

[5] Wartzman, Rick, *Wall Street Journal*, June 1, 1994

Villers has spent recent years running Families USA from his home in Concord, Massachusetts while the organization's staff is in Washington. Today, the foundation, which describes itself as non-partisan but definitely leans towards Democratic positions, is actively involved in Medicare-related issues. Villers has been a delegate to several national Democratic conventions, is a member of the ACLU President's Committee and Amnesty International USA's Executive Directors Council. He is also president and a board member of GrainPro, a company making hermetically-sealed grain storage units for developing countries. One may or may not agree with his politics, but everyone should admire his commitment and energy devoted to giving back to a society that has given much to him.

**Hardware and software developments in the late 1970s and early 1980s**

By 1980, Computervision was dominating the turnkey CAD systems industry. According to Daratech, the company shipped 620 systems in 1980 or 44% of the industry's total.[6] During this period, Computervision's research and development activity swung into high gear. Some of the major projects were:

**CGP-200 –** The CGP-100 computer proved to have less than desired graphics performance. To enhance its capabilities in this area Computervision developed a specialized graphics processor, the Graphics Processing Unit (GPU) to handle two-dimensional and three-dimension graphic manipulations. The combination of the GPU and a CGP-100 was marketed as the CGP-200 and CGP-100 was eventually dropped from the company's product line.

**CGP-200X –** This was an upgraded and repackaged version of the CGP-200. It was Computervision's primary computer system starting around 1982.

**Instaview –** Although Tektronix had added limited refresh capabilities to its storage tube products, it was becoming obvious that more interactive graphics capabilities were needed by CAD users. Computervision's answer was the Instaview which was introduced at the November 1978 AUTOFACT conference in Detroit. The was a monochromatic 512 line raster terminal that Computervision sometimes described as a 1024 line unit. In reality, static images were displayed at 512 line resolution while dynamic images took advantage of the full 1024 resolution. Text was displayed on the left side of the screen in an area where graphics was excluded. Primary user input was via a 17-inch by 24-inch tablet containing a user-defined 427 button menu. The Instaview C was introduced in several years later. It supported 64 colors at 512 line resolution. A high resolution version, the Instaview HC was subsequently introduced with 1280 by 1024 resolution and 262,000 colors.

**APU –** The Analytic Processing Unit or APU was Computervision's answer to the trend towards 32-bit computers for CAD support. Initially, it was not intended to replace the 16-bit CGP machines but rather to be directly linked to those machines and provide 32-bit processing for analytical tasks such as finite element analysis. Development took much longer than expected and this device never lived up to expectations. From a performance point of view, it was in the same category as a Digital

[6] *Worldwide Shipment of CAD Systems for 1980*, Daratech

 

VAX 11/780 except the 11/780 had been on the market for over four years by the time the APU went into beta test.

**CADDS 4 –** This new version of Computervision's CADDS software was required to take advantage of the graphics processing capabilities of the CGP-200 and the Instaview terminals. This version of the software had enhanced graphics capabilities such as geometry creation in any plane, not just a plane orthogonal to the current view.

**CADDS 4X** - This software upgrade was needed to take full advantage of the new processing capabilities of the CGP-200X and the APU. Customer deliveries began in the latter part of 1983, nearly two years late by some estimates.

**MEDUSA –** In November 1982, Computervision acquired Cambridge Interactive Systems, the Cambridge, England company responsible for the development and support of MEDUSA. The software was also being marketed outside of Europe by Prime Computer. Computervision began marketing MEDUSA running on Digital VAX computers and continued to support Prime's sales of the package. MEDUSA was an effective drafting program that had decent three-dimensional capabilities. According to Jim Barrett, Computervision's president at the time, this was Computervision's first step towards offering customers the choice between bundled turnkey systems and modular software.

Until 1984 Computervision used the Designer designation for its different systems based upon the previously described hardware and software products. At the low end was the Designer M which was Computervision's entry level system, introduced in November 1981, which could also be utilized as a remote system. As a remote system it was referred to as the Designer R. It consisted of a CGP-80 computer and either CADDS 2, CADDS 3 or CADDS 4 software. The CGP-80 was a reduced capability version of the CGP-100 that was used to support CADDS 2 and CADDS 3. A higher performance CGP-180 was used to support CADDS 4. With prices starting at $100,000, these systems could support either one or two Instaview M terminals which were specifically configured to work with the Designer M product line.

Prior to 1982, Computervision's primary product was the Designer IV which consisted of a CGP-100 processor, CADDS 3 software and typically two to six terminals. Although CADDS 4 software would run on a Designer IV system, there were advanced features in that software that required a CGP-200 to be utilized. Starting in 1982, the Designer V became the company's primary product line. It replaced the CGP-100 with the newer CGP-200 which provided better Instaview support. The last system in this product line was the Designer V-X which incorporated the CGP-200X processor and supported CADDS 4X software as well as the APU.

### Overhauling CADDS software

By 1978, it was apparent to some of Computervision's development staff that CADDS 3 was being pushed to its limits and that an entirely new software product was needed – one with a better database architecture and improved graphics. It was also apparent that a new generation of computer hardware and operating systems was just over the horizon. A group of four individuals; Ken Versprille, Bill Stanley, Tom Jaskowitz and Roger Roles, put together a plan for a new CAD/CAM system they initially called CADDS 4. Indicative of the relatively open management style of Computervision at the time, the four were given a chance to pitch their plan to the company's executive management. According to Versprille, they made a technical pitch ignoring the business issues surrounding such a decision and were shot down.

They were determined that a new system was necessary for the future health of the company and after licking their wounds, went back for another shot at convincing management that this was the right thing to do. This time they were successful and were given the task of proceeding with developing a new system fundamentally from the ground up. Since the Instaview terminal was just about ready to be shipped, the CADDS 3 people had the significant task of adapting that software to work with the new raster graphics technology.

Bill Stanley totally redesigned the CADDS database to use a concept of records and sub-records while Versprille worked on the graphics portion of the system. CADDS 3 graphics used a separate file for each view and wrote the graphics directly to the display terminal. This was a fairly common technique for storage tube-based graphic systems since images could not be changed except by erasing and rewriting the image. The new CADDS 4 software used a three-dimensional display file concept that was more conducive for use with raster displays where individual elements could be moved, deleted or changed at will.

Overall, the CADDS 4 software was a significant improvement over CADDS 3, particularly for three-dimension mechanical and engineering design. A change made in one view of a model, was immediately reflected in other views and geometry could be created on any arbitrary plane. Computervision also split the software into numerous different modules for marketing purposes.

The CGP-200 eventually proved to be somewhat underpowered for three-dimension graphics and planned software developments such as solids modeling. As a consequence, the company enhanced and repackaged the CGP-200 and introduced it as the CGP-200X in 1982. In order to take advantage of its new capabilities a revised version of CADDS 4 was required. This version of the software was known as CADDS 4X and it was the primary Computervision product throughout the balance of the 1980s and into the early 1990s.

**The Analytic Processing Unit (APU)**

By 1980 it was fairly obvious throughout the CAD/CAM industry that computers more powerful than contemporary 16-bit minicomputers were going to be needed to support the next generation of software that would be more database and solids oriented. At about the same time, a new crop of 32-bit computers such as the DIGITAL VAX 11/780 and Prime 750 were becoming more widely used by CAD software vendors. Computervision was well aware of this trend but also recognized the difficulty of making the transition from its current 16-bit CGP machines to a new generation of 32-bit computers.

The plan was to develop a 32-bit computer that would attach to one or more CGP machines and could be used for computationally intensive tasks such as solids modeling, finite element analysis and database management. This computer was called the Analytic Processing Unit or APU. On occasion it was also referred to as the Auxiliary Processing Unit and some industry observers occasionally called it an Attached Processing Unit. Mostly it was simply referred to as the APU. While the company did not plan to initially port all of CADDS 4X to the APU, that was the long term plan. From a performance point of view, the APU, which had a 225 nanosecond cycle time and a 16KB cache memory, was somewhere between a VAX 11/750 and a VAX 11/780.

By now Computervision was a fairly substantial company and it tried a matrix management approach for the APU project. This did not work very well and the company's top management realized not much was being accomplished. The lack of progress was causing credibility problems with customers and financial analysts. In either late 1982 or early 1983 a crash project was put in place to ready the APU for the November 1983 AUTOFACT conference. Masood Zarabian was put in charge of a new team of programmers with Ken Versprille as the technical lead. The team moved to a separate building in order to focus specifically on the task at hand. Several problems became apparent fairly soon. One was that the hardware engineers (the computer gypsies mentioned earlier) who had designed the APU had left Computervision. Another problem was that the software work done to date had redundancies and gaps in what had been accomplished. For example, there were two separate groups working on compilers for the APU.

Computervision customers who had access to early versions of the APU were somewhat underwhelmed. According to a Merrill Lynch report around this time, "The predominant complaint of CV users who have evaluated the APU is that it is too little, too late in terms of CPU horsepower and does not improve the response time of the workstation."[7]

Zarabian, however, was proving to be an effective manager. Versprille relates the story of one employee who was quite ill who Zarabian kept on the company payroll longer than perhaps was required. This resulted in the programmers pulling together behind someone they perceived to be a leader they could follow. Zarabian also felt that they needed to focus on three goals regarding APU software: 1) prove to the analysts that the APU was a viable machine and that Computervision strategy was valid, 2) create a deliverable product that could help drive the company's revenues and 3) do it right once the first two objectives had been met. It took about ten months, but the team had a working system by the end of 1983, nearly two years after it was initially expected.

One of the major problems the development team faced was the instability of the APU hardware. The machine consisted of four primary circuit boards and due to either design or manufacturing problems there was an excessive amount of crosstalk between these boards which would cause random machine failures. These problems were never fully resolved and the APU had a minimal impact on the company's fortunes. It was too little and too late and really did not solve one of the biggest problems facing users and that was improving the performance of interactive tasks such as calculating the intersection of two surfaces. One of the major problems was the difficulty Computervision had getting third party software firms to port their software to the APU. Packages committed for delivery included ADAMS (dynamics), UNIRAS (finite element analysis), ADLPIPE (piping analysis) and COSMOS (finite element analysis).

There was one aspect of the APU software project that would eventually have a major impact on Computervision and some of its staff from this period. Zarabian and Versprille brought over a team of programmers from the CADDS group to initiate the development of a solids modeler on the APU. There were nine programmers in the group and the manager was told to recruit another nine. After some number of months they

[7] Merrill Lynch Report, September 14, 1982 as noted in Weisberg personal papers

 

determined that very little had been accomplished because the group was working on other tasks of interest the project leader. Versprille and Zarabian ended up firing the manager, Vladimir Geisberg, who then went to work at Prime Computer developing solids modeling software there.

### Phasing out computer manufacturing

In August 1982 Allen gave up his titles of president and CEO to James Barrett, a former Honeywell vice president. Allen's comment at the time was that he "wanted someone who came from the multi-million dollar corporate environment and who had experience competing against IBM."[8]

Well before the APU began shipping, Computervision realized that a new approach was needed regarding the company's long range plans for computer platforms. In late 1982 Computervision told a number of computer vendors that the company would eventually shift from building its own minicomputers to using industry-standard workstations which could be networked together. This was not a decision made lightly. David Friedman, the vice president responsible for hardware engineering, and Bob Callaway, the vice president of manufacturing, particularly fought the idea.

Throughout the first half of 1983, the decision of which workstation vendor to go with swung back and forth between Apollo Computer and Sun Microsystems. The other contenders were quickly eliminated for either technical or business reasons. A key sticking point in the negotiations was that Computervision wanted manufacturing rights in order to keep its plants busy. Apollo had been around several years longer than Sun and had already signed up Auto-trol Technology, Calma and Mentor Graphics as OEM customers. A major advantage Apollo had in this competition was that it was located in Chelmsford, Massachusetts, just a few miles from Computervision's headquarters in Bedford. Sun, of course, was out in Silicon Valley.

There were two other major differences between the two companies. Apollo had been founded in 1980, before some of the standards that swept the computer industry in the 1980s became well established. As a consequence it developed its own operating system, AEGIS, which while it was UNIX-like was not truly UNIX. In a similar manner, Apollo's networking was based upon a proprietary token-ring methodology. These were good technologies but they were not industry standards. Sun, on the other hand, was fully committed to industry standards and used the Berkeley version of UNIX and Ethernet networking. The other major difference between the two companies was that Sun was more willing to have Computervision actually manufacture much of the workstations it would be selling.

In June 1983[9], a Computervision purchasing manager called Sun's president, Vinod Khosla, and told him that they were going with Apollo. Khosla and Scott McNealy who was vice president of manufacturing at SUN at the time, took a redeye flight to Boston that night and showed up uninvited in the Computervision lobby the next morning. They insisted in calling everyone in the company they knew, but no one was in a position to help them get the procurement decision reopened. Finally, one vice president convinced them if they left the lobby and returned to Sun's local sales office in

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[8] *Business Week*, December 20, 1982, p. 76C

[9] Although some sources put this call in July 1983, I have personal notes that as of the June, 1983 NCGA Conference in Chicago, I was already aware that Computervision had decided to use Sun hardware.

 

Boston, Barrett would call them. They got the call several hours later and according to Khosla, Barrett's comment was: "We have decided and here is why. You are a 40-person company and you have an incomplete product. We love your technology, but there is no way you can supply it. Apollo is the standard in the industry, well financed and well managed."[10]

Khosla and McNealy did not give up and convinced Barrett to give them another shot at Computervision's business. The result was that Sun succeeded in replacing a shocked Apollo as Computervision supplier of workstation technology. Sun was awarded a $40 million contract for workstation components. Under the deal, Computervision actually built the workstations using its own Instaview graphics technology. At this point in time, Computervision had far more capability in the graphics area than either Sun or Apollo, particularly more than Sun.

Needless to say, porting CADDS 4X to the Sun workstation was a major project that probably took a lot longer than initially contemplated. Five months later, at the 1983 AUTOFACT Conference in Detroit, all Computervision was able to demonstrate was a standard SUN 11/120 workstation connected to a CADDS 4 system via an RS-232 link. For software, they were able to download a CADDS drawing and view it on the Sun workstation. The statement made at the conference was that the company would have two-dimensional drafting running on the Sun platform sometime in 1984. They were able to do this by the May 1984 NCGA Conference in Anaheim, California.

The software they demonstrated at that conference, however, was quite different from CADDS 4. It used icon-based menus and may well have been an early version of Medusa ported to the Sun platform. Not much progress had been made by the time of AUTOFACT in October 1984 which was also held in Anaheim, although the company was able to demonstrate a fairly simple two-dimensional NC application. One of the problems they were having was that these Sun workstations had 50MB disk drives which were not large enough to support both the drafting and NC software – one or the other.

A year later, at the November 1985 AUTOFACT Conference in Detroit, Computervision still was not able to demonstrate CADDS 4X running on a Sun-based workstation. To put this situation in its proper perspective, CADDS 4X consisted of more than five million lines of code, mostly written in an older version of FORTRAN. The first step in the porting process was simply to rewrite this older code in Fortran 77 and then port it to the Sun platform running UNIX. Zarabian was asked once again to manage a time critical project and he had the programmers working two shifts. It was probably another six months, however, before the company was able to ship CADDS 4X running on the Sun-based CDS 3000.

## The mid-1980s are a period of transition

1984 was actually a great year for Computervision. Revenues soared 39% from the previous year to $556 million and the company earned $75 million. A sizable portion of this was as a result of winning a $99 million U.S. Navy contract in late 1983. Also in 1984, Computervision acquired GRADO in West Germany, a developer of PCB design software, and Organization for Industrial Research (OIR), a vendor of group technology software. The latter never made much of impact on CV's customers and was sold to International Technigroup in 1991.

[10] Harvard Business School case study, Professor Amar Bhide, December 14, 1989

As of mid-1985, the company's management consisted of the following key individuals:

- Martin Allen – Chairman of the board
- James Berrett – President and CEO
- Phillip Reed – Senior vice president and COO
- Richard Keiger – Vice president, finance and treasurer
- Robert Gothie – Vice president and group executive, North American Group
- Peter Chaison – Vice president, business development group (responsible for GRADO and the Metheus joint venture)
- Richard Paulson – Vice president and group executive, product group
- David Friedman – Vice president and general manager, product technology
- Thomas Sancha – Managing director, Cambridge Interactive Systems
- Masood Zarabian – Vice president and general manager, Applied Technology Division
- Bard Solomon – Vice president and general manager, OIR
- Ken Ledeen – Vice president and general manager, Personal Systems Business Unit.

In May 1984 Computervision held a major press conference in Boston to announce a new product strategy consisting of three major components.

**CDS 3000 –** This was the initial nomenclature for Sun workstations running Computervision software. Prices ranged from $35,000 for a basic workstation to $75,000 for a server version. Five software packages were announced at the May press conference including schematic data capture for electrical design, drafting, space planning, technical publications (actually Interleaf software) and a viewing program called FactoryVision. Database software from Rational Technology was also planed for the CDS 3000. Software prices ranged from $4,500 to $12,000.

The plans as of May 1984 were to begin deliveries in November. Sales of the CDS 3000 hardware took off rather slowly due to the lack of deliverable Computervision software. The company also began selling Sun workstations as Medusa terminals where the Medusa software actual ran on DIGITAL VAX computers but by mid-1985 CIS had ported the software to the Sun platform and it was being sold as Medusa/3000.

**CDS 4000 –** The bulk of Computervision's sales at this point in time consisted of CGP-200X minicomputers driving Instaview workstations, both monochromatic and color, and running CADDS 4X software. The APU was typically considered an option for this configuration. Previously this configuration had been referred to as the Designer V system. A new release called CDS 4000 Revision 2 with Ethernet and SNA communications support was planned for July shipment. Prices started at $250,000 for a system with two color workstations and basic CADDS 4X software.

In 1985, Computervision began selling Sun workstations as CDS 4000 terminals as an alternative to the Instaview units with the expectation that they would soon be able to directly support CADDS 4X software. By mid-1985, a boundary representation solids package, Solidesign, was fairly well integrated into CADDS 4X except that it did require that an APU be part of the configuration. On occasion Computervision still referred to these systems under the Designer VX nomenclature.

Figure 12.2
CDS-4000 System with Instaview Terminal

**CDS 5000 –** In 1983 Computervision signed an agreement with IBM to resell that company's 4300 series computers, primarily as database management machines. Running the VM/CMS operating system, these systems could support up to 64 simultaneous CDS 4000 users accessing databases up to 40 GB in size. Announced prices ranged from $485,000 to $650,000. The company initially referred to its software for these computers as Product Database Management although later they picked up the more industry standard term of Product Data Manager.

The general impression was that Computervision was trying to offer something for everyone and glossing over the difficulty of making it all work together. Reselling IBM mainframes seemed to be a particularly difficult stretch for a company that primarily was used to having engineers selling design and drafting systems to other engineers.

**Personal Designer –** Complicating this product mix, in September 1984 Computervision began shipping its first PC-based system, the Personal Designer System. With MicroCADDS software developed by Seattle-based 4-D Graphics, a Personal Designer System including a PC/XT sold for $13,580. Bezier curves and surfaces added

 

$2,800 to the price tag. A PC/AT version was also available at $17,890 and customers could purchase just the graphics hardware and software for $9,980 if they wanted to install the system on a PC they already owned. There was no ability to share data with either a CDS 3000 or CDS 4000 system although a CADDS viewing program was available.

The Personal Designer, which eventually was joined by a number of other PC applications, resulted in the company establishing its first domestic dealer channel. Although this was much more comprehensive software than what Autodesk had at the time, the price tag eventually proved to be too high for the product to be generally competitive with AutoCAD. In June 1985, a three-dimensional architectural design package developed by one of the company's French customers was added to the Personal Designer product line. Called Personal Architect, the software sold for $9,200.

**The first major restructuring**

If 1984 was a great year for the company, 1985 was a disaster. Revenue dropped to $441 million and the company incurred an $81 million loss. As these losses began to mount, Computervision laid off 950 people during the first part of 1985. By the end of the year it had laid off a total of nearly 2,000 people and closed its Sanford, Maine manufacturing plant as it began to de-emphasize the manufacturing of its own computer system. By mid-1985, it was obvious that Computervision was repositioning itself to be able to react more quickly to changes in the computer hardware end of its business by turning to standardized products made by other firms.

The problem was that with CADDS, Medusa, Personal Designer, Metheus, CDS 3000, CDS 4000, CDS 5000 and a myriad of other products, Computervision simply had too much on its plate. As I wrote in an Auto-trol report at the time, "CV is a company in transition and it does not seem that the transition is going well."[11]

Robert Gable became chief operating officer and vice chairman in September 1985 and Jim Barrett, as president and CEO, planned to focus on strategic issues and relationships with major customers. This setup lasted just six months and in March 1986 Gable replaced Barrett as president and CEO. Barrett went on to become chairman and CEO of Honeywell-NEC Supercomputers, a joint venture that planned to market very large computers in the United States.

**Computervision works to get back on track in 1986 and 1987**

In 1986 Computervision's business regained some of the momentum it had lost in 1985 as revenues recovered to $494 million and then in 1987 they grew another 14% to a record $565 million although profits of somewhat less than $20 million in 1987 were far below the $75 million the company had earned in 1984. By the end of 1986, nearly 60% of the company's business was international and it would increase in subsequent years until it reached 67% in early 1992. The weak 1985 results, however, were probably a major reason behind James Barrett's departure as president and CEO and his replacement by Robert Gable who had been COO. Gable had been a director of Computervision since 1974 and had joined the company full time in 1985 after a long career with Kidde, Inc.

In 1984, Computervision and Metheus Corporation of Hillsboro, Oregon formed a joint venture to design and market CAE products for the electronics industry.

[11] Weisberg personal papers

Computervision made a $220,000 investment in what was called Metheus-CV, Inc. and loaned the joint venture $10 million. This operation never really got off the ground and, in 1985, Computervision wrote off its investment in Metheus-CV and in 1986 consolidated the activities of the joint venture with its own operations.

From a software development point of view, 1986 saw significant progress in porting the five to six million lines of CADDS 4X code to the Sun platform running UNIX. This new version of the company's flagship software retained the older user interface involving typed commands or the selection of these commands from a tablet menu along with new capabilities involving on-screen icons and pop-up menus. CADDS 4X's 2,000 commands were logically organized into panels of 24 icons each. Switching between menus was facilitated by stacking the menus on the screen like a deck of cards so the user could rapidly move from one menu to another by clicking on the portion showing. The UNIX version of the CADDS 4X software took advantage of the multi-tasking and multi-window capabilities of the SUN operating system. As an example, an NC part programmer could see tool path geometry while at the same time view the text version of the tool path.

By June 1986, there were 15 customer sites running beta test versions of the Sun software and by the end of the year, the company was able to claim that the porting was virtually complete. The major exception was some of the more advanced NC software which would take until sometime in 1987 to complete. The new UNIX version of CADDS 4X was file compatible with the CDS-4000 version of the software, at least from its ability to read and write data files without translation. Users of older CADDS 3 and CADDS 4 systems were faced with the need to install at least one CADDS 4X system and translate data to that format before they could move on to the UNIX version.

On April 30, 1986 the company re-branded the CDS-3000 Sun workstations under the CADDStation label. These units consisted of Sun produced CPUs and Computervision graphics controllers along with the latter company's console packaging. This approach was intended to meet two objectives. First, Sun Microsystems still did not have particularly strong graphics technology. Second, by producing as much of each workstation as it could, Computervision kept a significant portion of its manufacturing infrastructure in operation, avoiding shutting down additional plants and taking substantial writeoffs. Probably the most significant aspect of the Sun relationship was that Computervision would be able to improve the performance of its workstations in step with the rest of the computer industry as Sun periodically introduced new higher-performance workstations and servers.

The CADDStations initially came in several different flavors utilizing Motorola 68010 and 68020 microprocessors with performance in the 2 to 4 MIPS range. Computervision sold these systems with both monochromatic and color displays and as diskless units as well as fully configured with disk drives and cartridge tape units. The nomenclature was 31X or 32X where the 31 referred to a 68010 microprocessor and the 32 referred to a 68020 microprocessor while the X was replaced by an M for a monochromatic display, a C for a color display and an S for a server. CADDStation hardware prices ranged from $14,000 for a very basic diskless unit to nearly $100,000 for a fully configured high-performance color workstation. Typical CADDS 4X systems probably averaged about $70,000 per seat at the time including software. In 1986 there was still debate within the computer industry regarding the relative effectiveness of the

 

Ethernet networking being used by Sun compared to token-ring networking promoted by Apollo and IBM. By early 1987, CADDStations represented approximately 50% of Computervision's revenues.

One of the primary design objectives for the CADDStation was to make the unit's graphics capabilities software compatible with Sun Microsystems' own workstations. This way, customers would be able to run standard Sun applications on the Computervision hardware. In general, it seems that the company met this design objective although some packages probably required that SUN software such as SunCore and SunGCI be added to the configuration.

During 1986 Computervision's Cambridge Inactive Systems subsidiary continued to enhance Medusa, particularly in regards to platform support. The company now supported Digital's VAXstation II/GPX workstation, MicroVAX computers and Sun workstations. The company said that its cooperative marketing program with Digital was going well but its 1986 annual report ignored Prime Computer's sales of Medusa.[12] CIS also launched a relational database management system integrated with Medusa graphics. Called Assembly Modeler, by early 1987 it was in use for plant design applications at 30 European customer sites. Also, Computervision reported that it had sold a joint ownership interest in Medusa Revision 4.06 for approximately $5.3 million but did not identify who the buyer was.[13]

The company's Personal Systems business took off in 1986 with revenues up 75% over 1985. Computervision introduced a low-cost two-dimensional drafting package, microDraft, during the year. It also launched Revision 2.1 of Personal Designer with on-screen menus. In addition, the company continued selling Personal Machinist and Personal Architect. In late 1986 the company announced a bi-directional translator between Personal Designer and the CADDStation-based CADDS 4X software. *Computer Aided Design Report*, which was not known for its superlatives, declared this package had "become of the best mechanical CAD/CAM program running on a personal computer."[14]

In April 1987, Computervision set a Federal Systems Division under Robert Blauth. At the time, the multi-billion U.S. Navy CAD 2 procurement activity was getting into high gear.

There was no question but the CADDS 4X software was where the bulk of the company's interest was and where most of the development resources were being directed. CADDS 4X encompassed a broad array of software including:

- Finite Element Modeling
- Mechanical Simulation
- Physical Properties and Engineering Calculator
- Basic Surface Design
- Advanced Surface Design
- Imagedesign (color shaded image generation)
- Solidesign II
- Drafting and Dimensioning

[12] Computervision 1986 Annual Report
[13] Ibid
[14] *Computer Aided Design Report*, December 1986, p. 9

- CVNC (numerical control tool path generation)
- Electrical Schematic Design
- Autoboard SMT (PCB layout from its Grado acquisition)
- Building and Civil Sciences (a wide variety of AEC applications)
- Plant Design
- Mapping

Although Computervision's primary focus was mechanical design, the company was the second largest vendor of AEC applications by 1987 trailing only Intergraph in market share. As of mid-1987 the company was still selling CAD 4000 systems built around its own proprietary computer system. The APU term had long fallen into disfavor and it was now simply referred to as a 32-bit virtual memory central processor.[15]

**Prime takes over Computervision**

On Sunday, December 27, 1987, Prime Computer's president and CEO Joe Henson, sent a letter to Computervision's president Robert Gable stating that the following day Prime would initiate an unsolicited $13.50 per share tender offer for all of Computervision's outstanding stock. The offer represented just 70% of Computervision's revenues the prior year. This move probably did not come as a total surprise to Computervision's management in that Henson said that he had been urging such a merger since 1985.[16] Computervision had taken some steps to prevent a takeover without the company's concurrence. During 1987 Computervision's stock had traded in a range of from about $7 to $23, the latter value being before the major stock market crash in October. Just before the Prime offer, Computervision's stock was slightly over $9 so Prime's offer was attractive to the company's stockholders. Prime stated that it would pay for the acquisition out of its $500 million in available cash, most of which was the result of a convertible debenture offering the prior February.

Although the CAD industry was going through some consolidation at this point in time, this would be the largest acquisition by far up until then and the first one in which a public company was taken over in a hostile acquisition. Prime was about twice the size of Computervision, but just slightly more profitable. Henson had joined Prime in 1981 when it was a $365 million company and had grown it to be an almost $960 million vendor of high end minicomputers. About $175 million of Prime's revenue was CAD/CAM related except that little of that reflected Prime developed software.

Most of Prime's CAD revenue came from the sale of 50 Series computers supporting software such as Medusa, PDMS (Plant Design Management System developed by CADCenter in Cambridge England) and Ford Motor Company's in-house developed PDGS package. The company had entered the personal computer CAD market in October 1987 with the acquisition of Versacad (See Chapter 20). Prime had been slow in moving to the rapidly emerging client/server architecture and did not have any engineering workstations in its product line except for machines from Sun Microsystems and Silicon Graphics that it had recently begun reselling.

The bottom line was that Prime was in good financial shape but the future did not look particularly bright – hence the acquisition of Computervision would position the

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[15] Computervision Consultant Reference Guide, 1987
[16] *Wall Street Journal, December 28, 1987*

 

company in the rapidly growing systems business. Apparently, Prime's top management and the company's financial advisors did not realize the dynamic changes the turnkey CAD/CAM systems business was on the verge of going through.

Henson's position was: "The [CAD/CAM] industry is undergoing consolidation in the number of players. That being the case, we made the judgment that we had to get larger, and it became attractive to examine external means of growth…. In our view, Computervision, even more than Prime, can't remain independent."[17]

As often happens in this type of situation, Computervision rejected Prime's offer as being inadequate although its stock had been selling for just $9 just prior to Prime's offer. One of Computervision's first defensive steps was to threaten to make a major acquisition of its own as a way of raising Prime's cost for the takeover to an unacceptable level. Prime raised its offer to $15 per share with a "final offer," both parties fired off lawsuits and press releases.

One major defensive tactic Computervision threatened to put in play was a technique called a "poison pill." In effect, this provision in the company's bylaws would have dramatically increased the number of shares outstanding once a bidder acquired a 20% interest in the company. Computervision had put this provision in place on February 11, 1987 making it appear that the company was expecting a hostile takeover threat, although perhaps not from Prime.[18] Prime also objected in court to what it called an excessive level of severance compensation for top executives forced out by the acquisition. In its lawsuit, Prime attempted to get both of these issues overturned. At this point, Computervision claimed that it was in discussions with other, more friendly, companies who might acquire the company. No one ever came forward to claim that they were seriously considering making an offer for Computervision.

Finally the two sides sat down and worked out a deal that ended up with Prime acquiring Computervision for $15 per share or a total of $435 million. All this took less than six weeks – but it was a hectic six weeks. On January 28, 1988 the two companies signed a "Plan of Merger" agreement that made Computervision a division of Prime Computer. Nearly everyone the media interviewed seem to think that this was a good deal for both parties. Robert Herwick of Hambrecht & Quist said "This is a good fit. I think the deal is a steal. Henson should be congratulated." Even Phil Villers, one of the co-founders of Computervision and at this point president of Cognition chimed in with: "I'm realistic enough now to know that to be a world leader, you have to be much bigger than Computervision is now."[19]

In retrospect, while Prime management had a good idea of what that company's problems might be going forward, it does not appear that they appreciated the extent to which Computervision's CAD/CAM business would be changing in the near future or for that matter, how Prime's computer business would change. These were issues all the traditional turnkey vendors had to face: the need to unbundled software, the lost revenue when customers began purchasing standard workstations from the computer vendors, the need to support multiple platforms and the impact the personal computer would have on this industry.

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[17] *Computerworld*, January 11, 1988
[18] Computervision 1986 Annual Report
[19] *Computerworld*, February 2, 1988

 

**Computervision as a Prime Division**

There were relatively few immediate changes when the acquisition was finalized. Martin Allen was out as Computervision's chairman since that company ceased to exist as a separate entity but the company's CEO, Robert Gable, stayed on. Initially, Prime said that layoffs would be avoided and redundant personnel would be absorbed in other positions. It was made clear from the start that the company would split the combined company into two roughly equal in size divisions, one focused on CAD/CAM products and the other focused on Prime's traditional minicomputer markets. In early March, it did so and appointed Robert Fischer, who was running Prime's CAD division, to head the Computervision Division of Prime as well continue running Prime's efforts in this area. To no one's surprise, Gable resigned to "pursue personal interests."

While CADDS was clearly Computervision's flagship product, Medusa was more important than many outsiders realized. In Europe it represented nearly half of Computervision's business.[20] Since Computervision had acquired CIS, the two versions of Medusa had diverged significantly. The Computervision version ran on Digital VAX computers and Sun workstations while the Prime version ran only on Prime 50 Series computers. There probably was a market need for both Medusa and CADDS much as a number of years later Dassault Systemes would sell both CATIA and SolidWorks and UGS would sell both Unigraphics and Solid Edge.

Medusa was considered by many to be easier to use than CADDS and it worked with standard off-the-shelf hardware such as Digital VAX computers and Tektronix display terminals. While CADSS 4X had quite comprehensive surface geometry capabilities, Medusa was more targeted at the design of industrial machinery.

In a *Computerworld* interview Fischer stated that the plan was to develop a single version of Medusa and offer it on multiple platforms. It took until November 1990, but Medusa Release 12 provided the converged capability and added support for SUN and Digital workstations as well as Prime and Digital minicomputers. Fischer also alluded to plans for making another significant acquisition (see section on Calma acquisition below) and plans to introduce an Oracle-based data management solution called the Project Control System.[21] There was one major problem with this latter part of the game plan, the software ran on Prime 50 Series computers which were not particularly compatible with Computervision's existing product lines. Given time, bringing the two companies together probably would have resulted in some substantial cost savings through the elimination of redundant overhead expenses, duplicative office facilities and a larger combined sales and service presence in key markets.

On the other hand, bringing the two R&D teams together proved to be a particularly difficult task. As Versprille describes it, even in the company cafeteria the Prime people would sit on one side of the room while the Computervision people sat on the other side. While Prime did not have any software developed in-house comparable to CADDS 4X, under Vladimir Geisberg it had developed its own solids modeling package, PrimeDesign, introduced in April 1988. Computervision likewise had developed a solids-based package separate from the basic CADDS software called Solidesign II. There was a feeling among some of the former Computervision employees that Prime had copied some of the Solidesign II code in developing PrimeDesign.

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[20] *Computer Aided Design Report*, April 1988 p. 1
[21] *Computerworld*, March 7, 1988

Organizationally, Prime put Geisberg in charge of software development for the Computervision division. This did not sit too well with people such as Versprille who left before the end of 1988.

Strategically, there was a major dichotomy in Prime's direction. The company wanted to continue to be a manufacturer of computer hardware equipment even through it lacked the mass necessary to compete with the likes of IBM and Digital. Fischer was quoted at a Daratech workshop as saying, "One cannot become a large and profitable software only-company. If you look at some of the examples in the industry, you'll find that few have. Secondly, it is difficult to become large and profitable over a very long period of time as a remarketer of somebody else's hardware."[22] Yet that was the path down which Computervision was proceeding when Prime decided to take it over.

By early October 1988 it was clear that digesting the Computervision acquisition was going slower than initially expected and that revenue and earnings were suffering as a result. This led to a major management change. Joe Henson announced that he would be stepping down within a few months and that Anthony Craig, an IBM veteran who had most recently been running GE Information Services, had been hired to replace him.

Henson claimed that he had told the board the previous year of his plans to step down but it seems more likely that David Dunn, Prime's chairman, and the company's board of directors were gently forcing him out due to the difficulties the Computervision acquisition was causing and the lower than expected business results. A little over a year later Henson re-emerged as chairman and CEO of Legent Corporation, a systems software firm.

It is also interesting to note that in early October 1988 Prime initiated two anti-takeover moves of its own. It implemented a provision granting each stockholder one additional share of stock for each share owned if the company was acquired in a manner the board of directors did not approve. It also approved a "golden parachute" plan for executives in case of a hostile takeover. It seems clear from these moves that Prime management was expecting a hostile takeover attempt such as the one MAI Basic Four would launch the following month.

### Adding Calma to the mix

As if integrating the Prime and Computervision business units was not enough of a challenge, in October 1988 Prime decided to acquire the mechanical CAD portion of Calma from General Electric (See Chapter 11 ). GE had made it clear nearly a year earlier that it was looking for a way to gracefully exit the CAD industry and had already sold Calma's integrated circuit business to Valid Logic. Once it became clear that GE was trying to unload Calma, the company's revenues plunged precipitously. IDC estimated that Calma did $133 million in CAD/CAM/CAE[23] of which perhaps $90 million was in mechanical CAD. This latter figure had dropped to an estimated $50 million by the time Prime stepped into the picture according to Daratech.[24]

While Prime had spent $435 million to acquire Computervision or a little less than one times revenue, it was able to pick up Calma's $50 million in revenue for a pittance, probably only a few million dollars. As part of the deal, Prime assumed the

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[22] *Computer Aided Design Report*, April 1988, P. 1
[23] *Computerworld*, October 17, 1988
[24] *Computer Aided Design Report*, November 1988 p. 9

responsibility for supporting Calma's installed base of 800 customers and other liabilities and GE agreed to buy some unspecified number of CAD systems from Prime in the future.

To be blunt, this deal was done primarily to acquire Calma's customer base and was only slightly influenced by the opportunity to acquire additional technology. Calma's DDM (Design, Drafting and Manufacturing) software ran on Apollo workstations and Digital VAX computers. Prime's Computervision Division was deeply committed to Sun Microsystems, particularly for its CADDS software and was not particularly interested in also supporting Apollo workstations at the same time. It did have some experience with Digital hardware which was used to support Medusa.

Fischer stated that Prime would operate Calma as an independent business unit for at least a year after the acquisition was completed. This deal was subject to government approval and was not expected to actually close until late 1988. At that point Prime intended to "enhance the Calma product for at least a couple of years" and "support the product for at least five years after the merger." Fairly soon after the acquisition was completed, Prime began encouraging DDM users to migrate to its CADDS and Medusa product lines. As part of the deal, Prime also acquired Calma's Dimension III plant design software. This they continued to support and market well into the 1990s.

An important aspect of the deal with GE was that Prime was to be given preferred vendor status at GE. With the acquisition of Calma, Prime became the second largest CAD/CAM vendor after IBM. This ranking was based upon the sale of hardware as well as software and services into this market sector.

**Battle with Bennett LeBow for Control of Prime**

By early November Prime was making progress, although perhaps somewhat slower than originally contemplated, in digesting its Computervision acquisition and was gearing up to take over what was left of Calma when a new battle for control of the company erupted. MAI Basic Four, a California company a third the size of its intended target, initiated an unsolicited offer to acquire Prime Computer for $20 a share or $970 million. Prime's stock was selling for about $15 per share prior to the offer being announced. The actual offer was really more than this amount since Prime itself had about $500 million in debt that would have to be assumed by MAI Basic Four.

This was the era of junk bonds and corporate raiders who were taking over companies with high interest rate bonds and other financial vehicles and then dismantling these companies for quick profits. One such wheeler and dealer was Bennett LeBow who had taken over a company known as MAI Basic Four and was its board chairman. MAI Basic Four was a conglomeration of several companies, most notably MAI (Management Assistance, Inc.), a distributor of IBM-compatible peripheral equipment, and Basic Four, a manufacturer of small business computers. LeBow was also involved in takeovers of Western Union and the Liggett Group, a cigarette manufacturer. For the most part, LeBow would buy companies in financial trouble using third party financing and very little of his own money. He would then slash overhead, turn them profitable and then sell them off, entirely or in pieces. Although his business methods did not generate a lot of friends, he was successful at what he did.

LeBow and his partner, William Weksel, were not strangers to the CAD industry. In the early 1980s they had acquired a controlling interest in Information Display

Incorporated, a graphics equipment manufacturer that was moving into the CAD systems business. This did not turn out well and IDI filed for bankruptcy in 1984. Subsequently, Weksel ran into legal trouble regarding insider trading and the overstatement of financial results regarding IDI.

Prior to initiating this hostile takeover, Bennett and Weksel had indicated that they were interested in selling their 43% stake in MAI Basic Four through the firm of Drexel Burnham Lambert. This latter company was one of the powerful forces behind the junk bond craze and Michael Milliken, who subsequently went to jail for securities fraud, was the driving force behind this portion of the company's business. Drexel Burnham Lambert indicated that it was prepared, together with its investment partners, to provide $650 million in short term bridge financing and as much as $875 million in junk bond financing to facilitate the takeover of Prime. Complicating this unsolicited offer was the fact that MAI Basic Four had actually approached Prime earlier in 1988 and inquired if Prime would consider acquiring it. Prime responded that it was not interested.

When the offer was initiated, it was not clear if MAI Basic Four was serious about taking over Prime or simply was looking for a way to force Prime to acquire it or to pay it a fee to simply go away. The latter technique is typically referred to as "greenmail." Prime took the acquisition threat quite seriously, however. One of its first steps was to promote Anthony Craig to president and CEO immediately rather than continue the transition process whereby he was to take over from Joe Henson several months later. This was followed by both sides firing off lawsuits in court. MAI Basic Four tried to get Prime's anti-takeover provisions rescinded while Prime tried to find out more about how MAI Basic Four was actually going to fund the acquisition.[25] A federal judge in Massachusetts enjoined the tender offer until MAI Basic Four could provide an audited financial statement from Drexel proving that it had the ability to finance the deal.

The resulting company, if the deal was done on LeBow's terms, would have resulted in a company with $1.5 billion in debt and total revenues of $2.1 billion. LeBow claimed that this new enterprise would earn $200 million annually which would more than cover interest on the debt that was estimated to run upwards of $140 million annually.[26] Given that both MAI Basic Four's and Prime's minicomputer businesses were under tremendous competitive pressure from client/server systems and PCs, it was highly unlikely the company would have been as profitable as expected. According to one individual who was at MAI Basic Four at the time, the initial thought of the company acquiring the much larger Prime Computer had people excited, but as it dragged out it started to have a negative impact on morale and became quite distracting.

In late December 1988 MAI Basic Four claimed that owners of more than 50% of Prime's stock had tendered their shares although this claim was viewed with some cynicism. Prime was incorporated in Delaware and that state's securities laws required that shareholders tender 85% of the outstanding stock in the case of a hostile takeover. While the Prime takeover of Computervision had been reasonably civil, LeBow's raid on Prime turned virulent. When LeBow suggested to David Dunn, Prime's chairman and Craig in a letter that a negotiated transaction would be in everyone's best interest, the response was biting. Dunn's response cited wrongdoing by LeBow, Weksel, and to

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[25] *Computerworld*, November 28, 1988
[26] *Computer Aided Design Report*, December 1988, p. 6

 

Drexel's recent agreement "to plead guilty to multiple felonies, several of which involved the use of insider information."[27]

By the end of January the amount of stock tendered had risen to over 70%. Although this hostile takeover initially took Prime's employees by surprise, they soon rallied behind Craig with buttons claiming "No LeBow" and an employee group called "Employees Against the Takeover" was formed. Prime even orchestrated a rally at which 2,000 employees heard Massachusetts governor Michael Dukakis assail MAI's plans.

By early February 1989, Prime's stock was slightly over $20 per share and there was talk of a white knight coming to the company's rescue. One firm mentioned in this context was Ford Motor Company which had recently seen its arch rival General Motors acquire Ross Perot's Electronic Data Systems. MAI Basic Four extended its offer to mid-February and announced that it had an additional financial backer, Merrill Lynch & Company. Opinions by security analysts varied all over the landscape. Stephen Dube of Shearson Lehman Hutton, Inc. said "I think we are going to see an end to this battle very soon," while an unidentified analyst stated in regards to Ford "Yes, they're Prime's biggest customer, but I don't think they want to buy the company. I think the MAI acquisition is going to happen."[28]

One of the interesting sidelights to the battle for control of Prime in 1989 was the purchase by David Dunn, Prime's chairman, of a large $4 million mansion in San Diego. According to the *Computer Aided Design Report* this house had been built by Earl Gagosian, the founder of the Royal Inns hotel chain. Gargosian and everyone who subsequently owned the mansion suffered financial reverse after buying the mansion.[29]

In mid-April, the heat was building on Prime and the MAI deal looked as if it might be gaining momentum. Prime, acknowledged as much when it announced that it had directed its investment bankers to look for alternative buyers. The Massachusetts court that had issued an injunction against MAI proceeding with its tender offer until it got financial data on privately-held Drexel, announced that the injunction would be lifted ten business days after MAI sent audited 1988 financial statements for Drexel to Prime shareholders. This would allow MAI to proceed in Delaware court to void Prime's poison pill provision that allowed shareholders to buy additional stock at a discount during a hostile takeover. MAI said the Drexel financial statements would be in the mail as early as May 1, 1989. At this point it looked like the battle would culminate in a proxy fight at Prime's June 14, 1989 annual meeting.[30]

In mid-May Dunn challenged LeBow to either make good on his original $20 per share offer worth $970 million by June 2nd or call it off. Prime even offered to waive its poison pill provisions. MAI's immediate response was only that it was evaluating all aspects of its offer. Then on June 1st, MAI reduced the price it was willing to pay for Prime to $19.50 per share for shares outstanding as of April 12, 1989. This was about 75% of the total stock in the company. Employees' stock options would be converted to a combination of junk bonds and preferred stock with a value of $21 per share although the true value of this portion of the offer was probably worth a lot less. This revised offer

[27] *Computerworld*, January 9, 1989
[28] *Computerworld*, February 6, 1989
[29] *Computer Aided Design Report*, May 1989 p.15
[30] *Computerworld*, April 24, 1989

 

reduced the amount of cash MAI Basic Four would have had to come up with by $375 million.[31]

In early June, the two parties finally sat down face-to-face but about all they agreed to was to disagree. Wall Street analysts refused to speculate on the probable outcome of a business deal that was taking on the characteristics of a soap opera. Prime upset MAI and LeBow by postponing its annual meeting from June 14th to July 26th. MAI claimed that this could derail its proposed takeover of Prime in that MAI's financial commitments for the deal expired on July 31st.

While LeBow was continuing to fine tune and extend his offer, Prime's management was continuing its search for a white knight to rescue it from his clutches. They eventually found the company's "savior" in J. H. Whitney & Company, an investment banking firm which on June 23, 1989 agreed to offer $21.50 per outstanding share of Prime and to issue $22 in junk bonds for each of the remaining shares (i.e. employee options). Financing for the deal was to come from Shearson Lehman Hutton Holdings, Chemical Bank and First National Bank of Boston.

The deal was dependent upon Prime's shareholders tendering their stock, but this time with the approval of the company's board of directors. The actual acquiring company was a new entity, DR Holdings, formed by Whitney for the express purpose of executing this transaction. (DR stood for the initials of two Whitney partners.) Whitney claimed that it was interested in Prime as a going concern. According to Don Ackerman, a Whitney partner, "We are *not*, I repeat, *not* interested in breaking up Prime and selling off its parts." This is not what industry observers would have expected if MAI had been successful.[32]

As a last gasp, MAI Basic Four in mid-July offered to buy just the Prime minicomputer business for $450 million in cash and $150 million in bonds which probably were worth a lot less than their face value. This would have returned the company to roughly its original state prior to Prime's acquisition of CV. In retrospect, the company's management probably would have been better off accepting this last minute offer and moving forward with just the former Computervision portion of the business and other elements of its CAD software product mix.

On July 26th Prime delayed its annual meeting once again until August 9th. For a time, it looked as if the Whitney offer might unravel as Prime reported mediocre financial result for the previous quarter with a loss of $19 million and revenue down 7%. (A few weeks later MAI Basic Four would report that it had lost $46.2 million in the same quarter and its sales had dropped 30% to $51.8 million.) Considering the confusion over the MAI takeover and the search for a friendly acquirer, this probably should have been expected.

Chemical Bank and First National Bank of Boston put pressure on Whitney to raise additional equity to fund Prime's ongoing needs. In late August, the Whitney buyout was finally completed as 91% of Prime's shares were tendered. The entire LeBow episode took nine months to run its course and when it was over it was hard to identify any winners other than the lawyers and investment bankers. One significant effect was that Prime's top management was almost totally focused on fending off LeBow at a time

[31] *Computer Aided Design Report*, July 1989 p.15
[32] *Computerworld*, June 6, 1989

 

when they also had their hands full trying to fit together the Prime, Computervision, Calma and VersaCAD pieces of this complex vendor of software and hardware.

**Recovering from the MAI Basic Four assault**

As part of the Whitney takeover Anthony Craig was replaced as Prime's president by James McDonald, the former chairman of Gould Inc., a one-time battery manufacturer that had tried unsuccessfully to expand into a number of high tech businesses. He had previously spent 21 years with IBM. McDonald's primary task was to try to make some senses out of a convoluted software product line that ran on a hodgepodge of computer systems including Sun workstations, IBM PCs, Digital VAX computers as well as Prime 50 Series machines.[33] As part of the acquisition by Whitney, Russell Planitzer, who had been a Whitney general partner since 1981, replaced Dunn as chairman. The new management made repeated statements that all the company's product lines would be maintained but it was obvious that changes would not be long in coming.

Even the principals involved perceived this to be a fairly risky deal. In order to protect itself from the possibility of the reconstituted Prime eventually filing for bankruptcy, Whitney had set up a new entity, DR Holdings, to actually hold the stock in Prime. In addition, Shearson Lehman Brothers, at the time a division of American Express, loaned the company $500 million to help finance the buyout of Prime's stockholders. This was supposed to be a short term bridge loan which turned out to be a much longer term investment. When Prime eventually had problems paying even the interest on these notes in 1991, the interest payments were added to the loan balance.

Shortly after the deal culminated, Prime re-established the Computervision brand for the CADDS portion of its business. Interestingly, this was done after a group of users presented the company with a 400-signiture petition to do so at Computervision's September 1989 user group meeting. On the downside, Prime announced at about the same time that it would lay off 2,500 employees or about 20% of its worldwide staff. Planitzer claimed in a *Wall Street Journal* article that the layoffs would enable Prime to repay its bank debt in four to five years.[34] The company was reorganized into four business units: computer-aided design and manufacturing (Computervision), minicomputers, customer support and international operations.

By the second quarter of 1990, it looked as if Prime might be making a comeback. Although it was now a private company, Prime provided customers and employees with a limited amount of financial data. During the quarter, the company had operating profits of $50.1 million on revenues of $403.5 million. Unfortunately, interest expenses ate up all but $8.6 million of those profits. Prime claimed that CADDS sales during the quarter were 19% higher than for the comparable quarter a year earlier when the company was in the midst of its struggles with MAI Basic Four.[35]

**Computervision acquires Premise**

In April 1991, the Computervision division of Prime Computer acquired the assets of Premise, Inc. a small Cambridge, Massachusetts software firm whose primary product was a conceptual design package called DesignView. This software targeted

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[33] *Computer Aided Design Report*, September 1989 p.13
[34] *Computer Aided Design Report*, November 1989 p.16
[35] *Computer Aided Design Report*, September 1990 p.15

 

conceptual designers with a package that supported both dimension driven and equation driven design. Design View ran on both PC and workstation platforms. It was a two-dimensional sketching and modeling tool for engineers with a comprehensive constraint management capability.

The software worked with Microsoft's Excel and Word packages. Originally, Design View sold for $1,895[36] but by the time Computervision entered the scene the price for the PC version was down to $895 while the SUN and Digital versions went for $1,295. The company announced that it planned to keep Premise's original development team including president and founder Jon Hirschtick who eventually left Computervision and founded SolidWorks.

**The CADDS 5 era begins**

As of mid-1991, Computervision had perhaps 40,000 seats of CADDS software installed worldwide. Of these, about a third were second generation proprietary hardware systems that were fundamentally obsolete while the balance utilized some version of a Sun-based workstation.[37] A new generation product was badly needed as well as some new business practices that would make the company more competitive.

In 1985 Computervision began a significant development effort to create a new parametric, feature-based assembly modeler. The work was temporarily put on the shelf while the company's programmers were involved in porting the existing CADDS software to UNIX. Eventually it was merged with work being done at Prime and dubbed CADDS 5. In the interim, work continued on CADDS 4X.

In October 1990, Computervision introduced CADDS 4X Revision 6.0 which included a new Assembly Design module as well software for thermal analysis. Assembly Design enabled multiple users to work on the same product design, although not necessarily on the same part. If one user checked out a part for viewing and editing, other users could only view the part. The price for this client/server package was $8,500. The company also added raster editing and viewing software to CADDS 4X based on a technology and marketing agreement with FORMTEK.

ThermaLab was a new interactive thermal analysis package that included the capability to both create a finite element model and analyze the resulting model. This package sold for $10,000. Revision 6.0 also included Solidesign II which was Computervision's first attempt at incorporating history-based design in its software. The history tree created by Solidesign II could be edited and the model re-run to implement desired changes. The release also included enhancements to other CADDS packages including NURBS Surface Design and the CVNC machining software. [38] In April 1991, the company changed the name of the core CADDS 4X package from Design and Drafting to Solid Designer to reflect the fact that CADDS 4X now included the Solidesign II software module. At the same time, Computervision reduced the price of this core module from $24,500 to a more reasonable $15,500.[39]

In April 1991, Computervision began beta testing CADDS 5 at 11 customer sites and initiated early introduction sales to 30 customers beginning in July of that year.

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[36] *Computer Aided Design Report*, December 1988, Pg. 11
[37] *Computer Aided Design Report*, August 1991, p. 10
[38] *Anderson Report*, October 1990, p. 2
[39] *Anderson Report*, April 1991, p. 10

CADDS 5 grew out of a combination of the existing CADDS 4X software and Prime's PrimeDesign solids package. In early releases of the software, it was necessary to translate geometric data between the wireframe and solids modules. While this translation was mostly hidden from the user, there were other issues. One problem was that the display screen had to be cleared and the image regenerated when the user went from wireframe mode to solids mode.

Commercial shipments of CADDS 5 Release 1 began in October 1991.[40] CADDS 5 included feature-based parametric modeling, variational geometry, constraint modeling, sketching and an intelligent user interface – all the capabilities mechanical users were looking for in contemporary design software. The software was broken into more modules than before called Inter-Operable Packages. These included DesignView ($3,000), View and Markup ($3,000), Design and Drafting ($3,500), Solid Modeling ($6,000) and Parametric Design ($12,500). A bundle of modules including wireframe, basic surface and solids design, CGM plotter output, and the ability to use other applications once they were available was sold as the Premium Engineering Package for $24,500. This did not include drafting which pushed the price somewhat higher.

A typical Sun SPARCstation 2 had a list price of around $33,000 so a complete CADDS 5 seat would have set a customer back nearly $60,000. While this was expensive by 1991 standards, large customers were typically able to negotiate significant quantity discounts. CADDS 4X users could upgrade to the Premium Package for $9,800 except that the upgrade fee would be waived if the customer was using SPARC-based workstations and ordered the upgrade prior to December 31, 1991.[41]

CADDS 5 was not simply an enhanced version of CADDS 4X. It was new software written in C and C++. Probably the most significant improvement was the incorporation of dimension-driven solids modeling that put it in the same general class of design programs as PTC's Pro/ENGINEER. The company was four years late in doing so, however. The other major enhancement was a new user interface which employed the push-buttons and scroll-bar techniques described in the MOTIF specification published by the Open Software Foundation. When a menu icon was selected, information appeared on the screen that helped walk the user through that particular operation. This was very beneficial to new users just learning the software but experienced users probably felt that it slowed them down.

Computervision's introduction of CADDS 5 had several flaws beyond the normal bugs that one expects with new software that slowed down its acceptance. There were probably more than a few customers who felt that they deserved to receive the new software as part of their maintenance agreement and should not be required to purchase it as an upgrade. Eventually, Computervision made the transition fairly painless from a financial point of view. Technically, there were two serious problems facing users wishing to switch to the new software. Probably most significant was the fact that many of the applications customers had been using with CADDS 4X were not yet available to work with CADDS 5 and would not be for some time. The second problem was that even though the user interface was significantly improved, it was quite different from what users were familiar with. This resulted in the need for fairly significant retraining.

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[40] Computervision Form S-1, June 5, 1991, p. 45

[41] *Anderson Report* July 1991, p. 2

Eventually, Computervision facilitated the transition by providing a CADDS 4-like interface as a user selectable option.

Work on CADDS 5 Release 2 began well before Release 1 hit the streets. In reality, it probably consisted of capabilities the company would have liked to have included in Release 1 but had to defer due to the pressure to begin shipping a new software package. Release 2 which included analysis, assembly design and manufacturing applications started beta testing in March 1992 and early sales to key customers in April.

One of the important aspects of Release 2 was the ability to import CADDS 4X designed parts and use that data in building CADDS 5 assembly models. This greatly reduced the operational difficulties of moving from CADDS 4X to CADDS 5 in situations where there already existed a large amount of design data in the older format and/or a desire on the part of the customer to continue using existing CADDS 4X systems. The expectation as of early 1992 was that many customers would continue to use CADDS 4X and CADDS 5 in parallel for some extended period of time.

New CADDS 5 modules and applications were launched on a regular basis. In mid-1992, a new NURBS-based free form shape design package was introduced for $15,000 along with a new integrated engineering analysis module with auto-meshing capabilities for finite element analysis users. The latter package could be used with or without the CADDS 5 Parametric Design module with prices starting at $14,000. For major automotive and aerospace users, these prices were acceptable as long as the software did what it was intended. For general product manufacturers, these were fairly steep prices and one of the reasons Autodesk and PTC started taking more and more business away from the Computervision. The company's product rollout schedule envisioned having all CADDS applications compatible with CADDS 5 by mid-1993

On November 4, 1991, as part of the CADDS 5 initiative, Computervision launched a software development initiative called CV-DORS (Developers Open Resource Software). Verspille was hired back by Zarabian to run CV-DORS. This was a set of object-oriented software libraries which provided access to Computervision's core technology including wireframe, surface and solids geometry. There were three targeted uses for this technology: 1) Computervision's programmers would benefit from having better development tools, 2) third party software firms could use it to develop applications that interfaced to the CADDS 5 database and 3) other firms could develop stand-alone applications that used CADDS 5 as a graphics engine. It could be used to create programs compatible with CADDS 5 or to create stand-alone applications that simply incorporated the company's graphics technology. The routines could be called by C, C++ and FORTRAN programs.

Computervision established a CV-DORS business unit with the express purpose of finding software companies to use this product. The cost was $50,000 for a developer's license while run time licenses started at $2,500. A typical customer was Imageware, a vendor of advanced surface design software. It licensed CV-DORS ISSM (Integrated Surface and Solids Modeler) in order to develop a direct interface to its Surfacer 3.0 product. Some of the other early adopters of CV-DORS were PDA Engineering (finite element modeling), Wisdom Systems (knowledge-based engineering design), Silma (robotic programming) and Point Control (NC software). End users included Aerospatiale, Alcoa and Rolls-Royce.

In July 1992 Computervision announced a significant new application called Concurrent Assembly Mock-UP or what was typically simply called CAMU. Users could assemble models of complex products containing thousands of parts, work on many parts simultaneously and quickly view how changes affected the rest of the assembly. This was one of the first of a new generation of product navigation tools to be introduced to the CAD/CAM industry. CAMU sold for $9,500 per license.

**Additional product and business developments**

Subsequent to the leveraged buyout by J.H. Whitney & Co., Prime went through a number of management changes. The key individuals as of early 1992 were:

- Russ Planitzer resigned from Whitney in November 1991 to devote full time to the company as chairman of the board.
- Jack Shields joined the company in January 1990 as president and chief operating officer and became CEO in January 1991, replacing James McDonald. Prior to joining Prime, Shields had been with Digital for 28 years.
- Kathy Cote who had been with the company since 1986 was president of PrimeService.
- Mike Forster was president and general manager for Europe/Middle East/Africa. He joined the company in 1988 after 23 years with IBM.
- Delbert Lippert was executive vice president, general international area and operations. He joined the company in July 1990.
- Don McInnis was vice president and general manager, CADDS Business Unit. McInnis joined Prime in May 1990 after 13 years with Digital where he was vice president of that company's Engineering Systems Group. McInnis took over this position after Robert Fischer, who had been running the Computervision Business Unit, left in November 1990. Fischer joined SDRC as a senior vice president a few months later. (See Chapter 17)

While Prime's Computervision business unit was struggling to get CADDS 5 off the ground, the company's finances were deteriorating at an accelerating rate. In the second quarter of 1991, Prime reported a $349.7 million loss after taking a special charge of $329.5 due to accelerating the amortization of goodwill that had resulted mostly from its acquisition of Computervision. While this did not have an impact on the company's cash position, it did result in a weaker balance sheet.

The larger problem was that total revenues, especially from the company's 50 Series computers, had declined 13% to $352.8 for the quarter compared to the same period in1990. Even the Computervision business unit's revenue dropped by 9% due to unfavorable foreign exchange rates and purchase delays due to customers waiting for CADDS 5 Release 2 prior to making purchase decisions. *Computer Aided Design Report* summed up the situation fairly well in September 1991 when it stated that "Everything seems to depend upon CADDS 5 becoming a smash hit."[42] For all of 1991, the company had revenues of just over $1.2 billion, down about 6% from the prior year's $1.3 billion. These figures exclude the sales of Prime 50 Series computers.

[42] *Computer Aided Design Report*, September 1991 p.16

 

In the early 1990s Prime was facing several major trends that were changing the face of the CAD/CAM industry. Perhaps the most important was the move away from proprietary turnkey system to unbundled software running on industry standard platforms. Prime recognized this trend and took two difficult steps in response. One was to begin the switch from manufacturing its own workstations using a SUN CPU core to running on standard Sun workstations while the other was to unbundled its software.

A major second trend was the move away from expensive UNIX workstations to DOS-based personal computers. Although Prime had the second largest selling PC CAD package after AutoCAD in VersaCAD, it was slow in porting its CADDS product line to the PC platform and eventually lost significant market share to Autodesk. In fact, in mid-1990 the company was moving in the other direction when it launched a SunOS version of Personal Designer.

The third trend was the introduction of feature-based parametric modeling. Although CADDS 5 was a step in the right direction, it was late to market and lagged PTC’s Pro/ENGINEER functionality-wise. In one attempt to consolidate its operations, Computervision closed the VersaCAD facility in Huntington Beach, California and consolidated VersaCAD development work with the Personal Designer activity in Bedford.

By 1992, the company had ceased manufacturing its own workstations that previously had been used to support CADDS software. CADDS 5 ran on standard Sun workstations and work was underway to port the software to Digital workstation by the end of 1992 and to Hewlett-Packard workstations in 1993. Computervision was coming to grips with the concept that software needed to be designed and implemented on the assumption that it would run on multiple platforms when released rather than developing it on one platform and then subsequently porting the software to other platforms.

Other CAD companies were struggling with the same issue. It was a difficult challenge but one that needed to be surmounted if the company was to keep up with the rapid changes impacting the computer industry. Much of the decrease in CAD/CAM revenues was attributable to the fact that the company was no longer manufacturing its own high-margin workstations and was reselling standard Sun workstations whose prices were on a continuing downward unit price trend. As with other traditional turnkey vendors, the volume of software sales was not increasing rapidly enough to offset the decrease in hardware revenue.

**The product line becomes more and more complex**

Prime’s CAD/CAM business unit consisted of five product lines. CADDS and related products made up 72% of the unit’s 1991 revenues with about 49,600 seats installed, Medusa made up 15% of revenue with 13,000 seats installed, Dimension III (Calma’s AEC product) amounted to 5% of revenue with 8,800 seats installed, PC CAD (Personal Designer and VersaCAD) products made up an additional 5% of revenue but with over 100,000 seats installed while the company’s GIS products (System 9) brought up the rear at 3% of revenue and just 300 seats installed. From an organizational point of view, the Medusa and Calma portions of the product line were managed as part of the same product group.

At this point in time CADDS 5 ran on Sun Workstations, Medusa ran on Sun and Digital workstations and Prime 50 Series minicomputers, Theda electronic design software (included with the CADDS data) ran on Sun workstations, Dimension III ran on Digital and Hewlett-Packard computers and workstations, the System 9 GIS software ran on Digital and Sun hardware, the company's new Product Data Management software ran on IBM, Digital and Sun hardware while the Prime-developed PDM package, PrimeControl, ran on Prime 50 Series machines. In addition Prime was also marketing Ford's internally developed PDGS automotive design software that ran on 50 Series computers and Lundy display terminals although Ford was responsible for maintaining the software component of these systems. Combined with the PCs used to support Personal Designer and VersaCAD, the company had an incredible spectrum of hardware platforms to support, none of which ran all the software products and none of the software products ran on all the different hardware platforms the company was supporting.

The service and support of third party hardware as well as Prime and Computervision computer systems had become a major business activity by 1992. Prime was servicing hardware manufactured by Sun, Intel, MIPS, Wellfleet, and Tatung as well as its own products with a staff of over 3,000 individuals working out of 250 field locations around the world. This part of the business, which generated about 25% of the company's revenues, was consistently profitable and helped fund the rest of the company's operations. As of early 1992, 44% of this service revenue came from maintaining Prime 50 Series computers.

**Growth of Product Data Management**

Starting in 1990, Prime began placing increased focus on Product Data Management software although the company often used the term EDM or Engineering Data Management. The initial EDM product consisted of four modules: EDMVault for data storage, security and access control; EDMProjects for project definition, revision control and release control; EDMProgramming for customized application development and EDMClient for user access to the EDM database. With a Prime provided Sun server, a complete system cost $160,000.[43]

EDMClient was subsequently renamed EDMNavigator. In October 1991, a more competitive version of the EDMVault software intended for use by five to 25 individuals was offered for $24,900. One catch to this lower cost pricing was that only one user could access the software at a time. By 1993, Computervision was doing $20 million annually in PDM software and services. The EDM products could handle AutoCAD, Pro/ENGINEER and CATIA data as well as CADDS and Medusa files.

Although Medusa and Dimension III between them represented approximately 20% of the company's revenues, they appeared to be receiving a disproportionate smaller amount of management attention and R&D resources. It was still a distraction and the company probably would have been better served if it had focused all of its development resources on CADDS 5. The problem was that the company needed every dollar of revenue it could generate and the fear was that capping Medusa, in particular, would have cost it valuable revenue.

The other development conflict was between Personal Designer and VersaCAD. Personal Designer was not simply a PC version of CADDS but had its own user interface and database. It was perhaps the most comprehensive mechanical design package

[43] *The Anderson Report*, July 1990, p. 12

 

available on the PC at the time, but it was much higher priced than the competition. VersaCAD was a simpler package and priced more competitively but it was not the "in-house" product and once the California development group was closed down it ceased to get the development and marketing attention it deserved.

By 1992, Prime was fully committed to selling both unbundled software and packaged systems of both hardware and software. The company's customer base read like a who's who of global manufacturing companies including Audi, Fiat, Ford, Rover Group, Aerospatiale, Boeing, Rolls Royce Aircraft Engines, General Dynamics, Raytheon, Ericsson, General Electric, John Deere and Ingersoll Rand. Prime had 385 direct sales people selling CAD/CAM products as well as a growing group of value added resellers and distributors. It was one of the first large-scale CAD/CAM vendors to develop a VAR channel for its mainstream products.

**Computervision goes public once again**

In June 1992, privately-held Prime made the announcement that it planned to initiate a new public offering of its stock and to rename the company Computervision. At this point Prime had four primary areas of business; its CAD software activity anchored by its CADDS product line, the sale of computer hardware in support of its CAD business, the maintenance of a wide range of hardware products including Prime 50 Series machines, legacy CADDS systems, the newer Sun-based systems it had been selling in recent years as well as support of other hardware products from a variety of manufacturers and, finally, the manufacture of 50 Series computers.

The plan was for the new Computervision to retain the first three of these business activities and to sell the Prime 50 Series manufacturing activity to a management group that would apparently retain the Prime name. When the dust settled, Computervision would consist of an $800 million CAD business and an unrelated $300 million hardware services business. Of the CAD portion, approximately 25% was CAD/CAM software while the balance was somewhat evenly split between the sale of Sun workstation and the maintenance of the company's installed base of CAD systems.

The terms of the this new public offering initially had the company selling 15.8 million shares of stock at $18 to $20 dollars per share. Both *Computer Aided Design Report*[44] and *Engineering Automation Report*[45] commented that they felt this price was too high and would probably have to come down in order for the offering to be consummated. Computervision also planned to issue $300 million in three and five-year notes to pay off $323.5 million of existing debt. A key element in the offering was an agreement by Shearson Lehman Brothers to convert its $290.5 million debt into15.3 million shares of the refinanced company. DR Holdings would retain 16.9 million shares of stock in the company.

The overall result was that Computervision would be about equally owned by DR Holdings, Shearson Leahman Brothers and the public while the company's debt would have been reduced from $843 million to $359 million. Although substantially lower than before, this would still be much higher than the debt of any other CAD company, most of which were debt free. DR Holdings, whose only asset was its Computervision stock, would be left with over $500 million of debt. Interest on this debt ranged from 13% to

[44] *Computer Aided Design Report*, July 1992, p.13
[45] *Engineering Automation Report*, July 1992, p. 3

 

15.5% and DR Holdings was committed to pay it off by 2002. Unless Computervision turned out to be particularly profitable and have its stock price increase significantly, it would be very difficult for DR Holdings to avoid eventual bankruptcy.

When Computervision's stock offering finally occurred on August 14, 1992, the terms were far different than what had been proposed a few months earlier. Twenty-five million shares of stock was sold to the public at $12 per share rather than the $18 to $20 originally intended. Even this proved high and almost immediately the price of the stock fell below $10 per share. The company also sold $300 million in notes due in five to seven years. In addition, the company was unable to negotiate acceptable terms for selling the Prime 50 Series manufacturing business to a group of managers and, instead, decided to simply shut down that operation. This meant that users of Medusa or Ford Motor Company's PDGS software who were running on Prime computers would have to look for another platform.

One result of the lower offering price was that Shearson Lehman Brothers had to take a $177 million pre tax loss to offset the lower value of its existing loan to the company. After the offering, Shearson owned about 13% of the company, DR Holdings about 33% and the public 54%. Interest expenses on the company's debt dropped from $122 million annually to about $53 million which the company's president, Jack Shields, said was a manageable number well below Computervision's cash flow. With the price of the stock below $10 per share, it appeared almost certain the DR Holdings would end up filing for bankruptcy and they did so a short time later.

Within weeks, the situation turned from bad to worse. On September 29, 1992 Computervision announced that revenue for the third quarter would be below the prior year's quarter and below its expectations. The stock immediately plunged over $3 per share and subsequently dropped as low as $4.75. On October 22, 1992, the company announced revenues for the quarter just ended of $234 million, down 16% from 1991 and an operating profit of just $700,000. The company actually reported a net loss of $88 million due to costs associated with laying off 700 or 11% of its employees and the previously described recapitalization. Needless to say, the stockholder lawsuits were not long in coming.

**Getting back on track**

The November 1992 AUTOFACT Conference in Detroit was sort of Computervision's coming out party as a public company once again. The company had a large booth and Jack Shields was a highly visible presence at the show. The company announced that it would support Microsoft's Windows NT operating system but no commitment was made as far as which products this would involve or when such software would be released. They did show CADDS 5 running on DECstation 5000 workstations and promised Hewlett-Packard Series 700 UNIX workstation support within six months. Computervision was starting to be more amenable to third party component software. In addition to licensing raster software from FORMTEK, the company was also using HOOPS graphics software from Ithaca Software even though Autodesk owned 20% of the company at the time. The latter package enabled Computervision's programmers to substantially improve graphics performance.

One of the difficulties in porting CADDS 5 to these new platforms was that the software had over 2,000 global variables (data items that could be shared between software modules) and Digital had to redo its compilers four times before they could handle Computervision's software according to Versprille. Computervision development personnel felt that HP was the better platform but since both Shields and McInnis had come from Digital it was no surprise that the latter company's workstations got priority. By the third quarter of 1992, CADDS 5 sales began exceeding the sales of CADDS 4X and by March 1993 the company had shipped 5,500 seats. The primary CADDS 5 product was the Premium Engineering package which sold for $19,500. In addition customers could purchase subsets of the functionality under the brand name of CVware.

Computervision was pushing hard on the fact that CADDS 5 was a "hybrid" modeler. By this, they meant that users could model using traditional wireframe and surface geometry techniques or they could use the new solids-based parametric modeling capabilities of the software when applicable. The company's marketing department pushed the idea that competitive packages such as Pro/ENGINEER could only work with the parametric approach.

By 1993, the company's sales in the United States represented just 20% of its CAD/CAM business. Europe was 65% and Japan represented the other 15%. Since the company went public in 1992, it picked up million dollar plus orders from Citroen, Fiat, Jaguar, Texas Instruments, General Electric and Aerospatiale. Sales were rapidly shifting from the company's direct sales force to resellers. By March 1993 there were 300 such dealers with 350 sales people trained to sell Computervision products. The intent was to generate 30% of the company's CAD/CAM revenue through the reseller channel by early 1994.[46]

In an attempt to bring Medusa and CADDS 5 closer together, Computervision introduced a package called CVdesign. Users could move two-dimensional Medusa data to CVdesign, perform three-dimensional modeling tasks and then return the data to Medusa. This way, CADDS 5 large library of applications could be made available to Medusa users.

In other software areas as of March 1993, Computervision was continuing to promote THEDA for printed circuit board design, especially for products that were a combination of electrical and mechanical components. Calma's DDM software had been capped several years earlier but the company was continuing to sell Dimension III into the process plant design and shipbuilding markets as well as older CADDS AEC packages which were being converted to CVware applications. A new program was CVpvs, a visualization package built around HOOPS.

While the company was trying to rationalize its product line, it still had too many irons in the fire. According to *Engineering Automation Report*:

> "We still think that they are in too many different markets and that they should focus on the manufacturing industries where they have the most significant market share. They do have a strategy to bring Medusa and CADDS 5 closer together with less redundant software development. We would like to see them accelerate this effort."[47]

[46] *Engineering Automation Report*, March 1993, p. 6
[47] *Ibid*

 

While the company's product activity was becoming better focused, it was not exciting Wall Street. By April, 1993, Computervision stock had dropped to $3 and the board felt it was time for a change. For the quarter ending April 4th revenue was down 19% to $221 million and the company had a $10.4 million loss. Jack Shields was terminated by the company's board of directors and Russ Planitzer took over as president and CEO. This was Planitzer's first job as a senior operational manager of a major company. In addition, Delbert Lippert who was executive vice president for international operations was replaced by Cathy Morrison, Bruce Ryan who was vice president and general manager of U.S. operations was moved to a staff position and was replaced by David Lemont. (Lamont would later become chief operating officer of ICAD and then president of architectural software startup Revit.)

Planitzer mover quickly to put his stamp on Computervision. Doug Smith was made vice president of strategy and development while Garth Evans was promoted to the new position of vice president of worldwide field operations. Smith would subsequently become vice president of finance and administration in early 1995. Barbara Kaye Marx was hired away from Hill and Knowlton to take over as head of corporate communications. Marketing was reorganized into four business groups headed by Vincent Chaillou (Architecture, Engineering and Construction), Jay Atlas (Aerospace), Chuck Harris (Automotive) and Lawrence Gozzard (mechanical machinery). Atlas was hired away from Digital while Harris came from Hewlett-Packard. A new dealer organization called CVselect was set up under Pierre Violo to work with the reseller channel.[48]

These moves didn't have an immediate positive impact on the Computervision's financial results as revenue for the second calendar quarter dropped 26% from the year before to $217 million and the company sustained an $8.8 million loss. Over half the reduction in revenue came from lower hardware sales as the company began to reorient itself to being primarily a software and services company.[49]

Within a few months, there were signs that Computervision might be turning the corner. The company had been under tremendous competitive pressure from PTC as that company realized that Computervision's installed base was ripe for replacement by more up-to-date technology. CADDS 5 was improving with each release and long term customers began to be more comfortable with the company. One account in particular gave indications of a turn around in attitudes. Alcatel, a French manufacturer of telecommunications equipment had been a Computervision customer for some time but had recently installed 20 seats of Pro/ENGINEER. In a head-to-head competition Computervision won a order for up to 200 seats of CADDS 5 software.

According to *Engineering Automation Report* the three factors that impressed Alcatel were CADDS 5's ability to work with both explicit and parametric geometry, its CAM software and the previously mentioned CAMU package.[50] Other major orders in late 1993 included one valued at $4.5 million from Rover Group in England, a $5 million order from Hyundai in Korea for shipbuilding software (Hyundai had over 3,000 seats of

[48] *Engineering Automation Report*, July, 1993, p. 15
[49] *Engineering Automation Report*, September, 1993, p. 5
[50] *Engineering Automation Report*, November, 1993, p. 4

 

CADDS and Medusa installed) and $3.5 million order from window and door manufacturer Anderson Corporation.[51]

Perhaps the most significant announcement in late 1993 was the fact that Computervision was stopping the resale of all computer hardware. From now on customers would have to purchase workstations and servers from the hardware manufacturers themselves or from resellers. The company had been losing nearly $50 million per year reselling mostly Sun hardware.

Computervision took a $515.5 million one-time charge, $365.6 of which came from exiting the hardware business while the rest were costs associated with restructuring the company and the planned reduction of headcount from 4,700 employees to 2,700 over an 18 month period. Although revenue continued to drop, down to $184 million in the September quarter, the company's cash position continued to improve and it reported $50 million in the bank.[52]

At AUTOFACT that November, Computervision announced that it would support Silicon Graphics and Digital AXP workstations by mid-1994 and that new EDM software including a Design Document Manager and a Design Release Manager were available and that the entire EDM suite would be ported to Windows NT in early 1994. The company even demonstrated a prototype virtual reality system using SGI hardware and dVISE software from a company called Division.

**Trying to regain historical momentum**

By early 1994, the CAD/CAM industry was entering a new stage of maturity that was defined by:

- The end of the turnkey systems era with customers buying software and hardware products separately.
- Suites of software packages that utilized a single database without the need to translate geometry as users moved from one application to another.
- Design, analysis and manufacturing software that was feature-oriented and made extensive use of parametric relationships.
- Customer demands that software from one vendor needed to work with software packages from other vendors.
- A shift from expensive UNIX workstations to Pentium-based PCs running Windows NT.
- The prices for both workstations and PCs were dropping rapidly making software an growing portion of users investment in CAD/CAM technology.
- A move away from these systems being used by a small cadre of specialists to their being used as a primary design and analysis tool by a larger group of casual users.
- The shift away from direct sales forces to the use of resellers.

[51] *Engineering Automation Report*, February, 1994, p. 13
[52] *Anderson Report*, November 1993, p. 3

 

- Just over the horizon, an entire new category of lower cost mid-range CAD packages utilizing component software technology was getting ready to be launched.

Organizationally, 1994 started off at Computervision with Atillio Rimoldi replacing Don McInnis as vice president of research and development. Rimoldi had earlier worked for Computervision but for the past ten years had been with Intergraph in Europe, most recently running that company's European Mechanical Competence Center. Masood Zarabian along with McInnis and Ken Versprille, who had rejoined the company a few years earlier, left as part of a corporate down-sizing in early 1994.

In February 1994, I spent several days visiting Computervision for an *Engineering Automation Report* profile. A planned 30 minute meeting with Russ Planitzer ended up running nearly two hours and I came away impressed by both his plans for turning the company around and his focus on what this technology could do for the company's customers if applied correctly. My conclusion:

> "Right upfront, we think that Computervision might be the high-tech turnaround situation of the decade. It will not be pretty and there will be a lot of broken pieces when they are through, but CV is taking many of the right steps in trying to get this business turned around…Why are we optimistic about CV – in fact more so than most of the other people that cover this industry?.... probably more than anything else, it is looking beyond the immediate problems and seeing what could be if the company executes its current strategy effectively."[53]

Was I overly optimistic? – probably, but not by much. The company had a real shot at succeeding but it would take almost perfect execution to pull off the turnaround and in the end, the company simply was not up to it. Of the $660 million Computervision expected to do in 1994, CAD/CAM software and consulting services made up about $320 million, the balance was the service business it inherited from Prime. With a huge base of CAD/CAM systems installed at major manufacturing firms around the world, Computervision was still a force to be reckoned with. But this installed base was under ferocious attack by the competition, especially PTC.

Computervision was moving fast to slim itself down for the battles ahead. By the end of 1993, it had already terminated 1,000 of the 2,000 people it planned to lay off as a result of exiting the hardware resale business and the company had vacated nearly 900,000 square feet of manufacturing and office space. The problem was that is still had to pay rent on much of this property.

Computervision also began shedding business activities that were secondary to its primary mechanical CAD/CAM markets. The System 9 mapping software was sold to UNISYS and the THEDA electronic design software was in the process of being sold to Japan's Zuken. It was no surprise that the company was focusing its sales and marketing on the automotive and aerospace industries along with manufacturers of industrial machinery. Manufacturers of consumer products were of secondary interest primarily because Computervision lacked the styling software these companies wanted.

[53] *Engineering Automation Report*, March 1994, p. 6

 

Software development was also undergoing significant changes under Rimoldi. In particular, the company was attempting to reduce the duplication of effort in supporting its large portfolio of applications. Medusa and CADDS 5 were beginning to share core technology where applicable, especially in areas such as drafting and visualization. The use of component software technology such as HOOPS also facilitated the company's ability to support multiple workstation platforms. In addition, there was renewed interest in providing customers with more reliable software. CADDS 5 Release 5.0, which was in development in early 1994, was intended to have far fewer problems than earlier versions. One step in accomplishing this task was the effort underway to remove old obsolete modules from the source code. Rimoldi claimed that this latter work would reduce the size of CADDS 5's source code by 20%.

At the end of 1992, CADDS 4X still made up half the company's new CADDS licenses. By early 1994, this was down to 20% as the company struggled to facilitate the transition process for customers. Initially, Computervision did not realize how disruptive moving from CADDS 4X or earlier versions of its software to CADDS 5 would be for customers. By 1994, the message had been received and the company was providing users with written guidelines for making the transition and how to integrate parametric design into a user's product development process. Computervision even implemented a CADDS 4X user interface option for CADDS 5 users who wanted to stay with something they were familiar with during the transition.

One marketing tool Computervision was implementing at the time was a strategic plan for partnering with its customers called "Product Development Diagnostic" or PDD. The objective was to compare customer design procedures with other companies in the same general industry. This was a form of "benchmarking" that Computervision hoped would distinguish it from other software vendors given its huge installed base of users from which it could draw comparative information.

Although customers and prospects were charged for this consulting work, it was clear that the primary purpose was to get these companies to buy more Computervision software and to use it more intensely. One key feedback that Computervision received from early PDD assignments was the need to improve software quality, an input the company claimed it was taking to heart.

In addition to improved reliability, CADDS 5 Release 5.0 also incorporated improved parametric modeling capabilities that made it more competitive with PTC's Pro/ENGINEER. One key enhancement was the fact that associativity between the solids model database and drawings was now bi-directional. Hidden line removal performance for large assemblies was as much as eight times faster than in prior versions. Release 5.0 also incorporated optimization functions based upon parameters such as mass properties and constraint equations. As an example, if one dimension of a box changed, then other dimensions would change so that the volume or surface area of the box remained constant. The company was starting to invest an increasing amount of its development resources on PDM software. Overall, Computervision seemed to be making the proper moves to regain its former momentum in a rapidly changing industry.

As mentioned earlier, however, if Computervision was to be successful with its turnaround plans, execution would be key. Business execution in any high tech industry usually calls for management consistency, especially in sales. This was one area where Computervision started to show some chinks in its armor. In May 1994, Patrick Clark replaced Garth Evans as vice president of worldwide sales and Ted Dysdale was hired as vice president of North American sales. A few months later, Evans assumed a similar position at ICAD to what he had at Computervision while David Lemont became ICAD's chief operating officer. Francois Duliege took over as vice president of sales and marketing at the company's San Diego Business Unit which was now responsible for the Personal Designer and VersaCAD product lines. Drysdale had been president of a company called ASP Express while Duliege had been managing director of Computervision's French subsidiary.

Meanwhile, the company continued to receive million dollar plus orders from its traditional customers such as Ford, Rover, GE Transportation and Hyundai as well as new customers such as China Aerospace Corporation. By fall of 1994 the company was shipping CADDS 5 on both IBM RS/6000 and Digital Alpha workstations. The company was also broadening the capabilities of its PDM software to handle non-Computervision data files. As an example, at the EDMS Vision 94 Fall User Forum in Cincinnati sponsored by The Kalthoff Group, the company demonstrated a version of its Configuration Navigator that could handle Pro/ENGINEER data files.

**Striking out in a new direction with PELORUS**

Since the early 1970s, Computervision had had a software development operation in the San Diego area. This was the group that did the early development work on CADDS 3 and more recently had taken on the responsibility of supporting the company's PC software including Personal Designer and VersaCAD. For some time, leading up to the mid-1990s, this group was understood to be working on a project called "Liberator" that was going to be the company's AutoCAD "killer".

As this project progressed, the company's management concluded that the most significant work being accomplished in San Diego was the underlying technology being used by the software developers. A decision was made to productize that technology as a graphics application development platform and licenses it to third party developers as well as use it in-house to create new specialized applications.

In early 1995, this new development architecture was given the name "PELORUS" which is a device resembling a compass used by mariners to determine the location of a ship at sea. PELORUS was implemented using the latest software development techniques and standards such as STEP, OLE, object brokering, dynamic linking as well as standard graphics interfaces including Microsoft Windows and Motif. The software consisted of a large number of individual object-oriented tools that could be dynamically linked together when an application was loaded. These tools could be assembled into application-oriented suites that supported data management, modeling, user interface and graphics display functions using a program called the PELORUS Tool Engine. It was expected that most programmers would create applications using Microsoft's Visual Basic although a more comprehensive capability was available for programmers who wanted to work in C or C++.

A key feature of PELORUS was that applications created using this development platform did not need an underlying graphics systems such as CADDS 5 or AutoCAD in order to execute. In addition, applications developed with PELORUS were supposed to be interoperable. To ensure that this occurred, Computervision planned to test programs created by independent developers and once certified that they met the company's interoperability standards, would be designated as "PELORUS Powered."

The first PELORUS application was a Process & Instrumentation Diagram package called DesignPost P&ID. It was developed in partnership with Framatome S.A., a French nuclear engineering company. It was intended to be the first of a series of applications carrying the DesignPost label. It was priced at $2,500 and was targeted for shipment in March 1995. Similar packages intended for use with AutoCAD or MicroStation sold for perhaps $1,000 but required a copy of the underlying CAD package in order to function, raising the cost per seat to more like $5,000. Planitzer told the media and analysts not to expect significant revenue until 1996 or 1997 and that by 2000 the company's revenues would still be more than 50 percent CADDS based.[54]

One of the major shortcomings of PELORUS as initially announced was the lack of solids modeling and surface geometry capabilities. In April 1995, a major joint development effort with Mercedes-Benz AG was announced under which Mercedes-Benz would use PELORUS to develop a new generation of automotive modeling and styling applications. At the time the company had about 2,100 CAD seats installed, 1,200 CATIA and 900 an internally developed design package called SYRKO.

Under the agreement, Mercedes-Benz was to invest 150 man-years of effort over a three-year period adding SYRKO design capabilities to a suite of PELORUS-based applications. The project was to start with Mercedes-Benz installing 100 PELORUS development licenses. As the applications were developed, this was to lead to as many as 3,000 run-time licenses. Computervision would then sell these applications to Mercedes-Benz suppliers and other manufacturers.[55]

Also in early 1995, Computervision announced a drafting package based upon PELORUS technology called DesignPost Drafting. The plan seemed to be to attack AutoCAD with this package, especially in the mechanical drafting arena. The software was defined as being "event driven." If the user was in the middle of creating a string of lines, he/she could interrupt that process, open another drawing file, perform some function and then return to the first drawing and pick up right where it was interrupted. The software, which was priced at $2,995, also included dimension driven geometry, parametric equations, built-in symbol libraries and direct access to AutoCAD DWG data. It sounded almost to good to be true and that turned out be the case.[56]

PELORUS never really got off the ground. Few copies of DesignPost software were ever sold and the Mercedes-Benz agreement never resulted in marketable software. While Mercedes-Benz was excited about the potential of PELORUS when this relationship was launched, it soon became disenchanted as PELORUS failed to live up to its advertised capabilities. In summary, PELORUS never produced the technology and revenue that was expected and it turned out to be a major distraction from the companies main CADDS business.

**Getting the CADDS business back into high gear**

By mid-1995, business was looking up for Computervision. The focus was now on what the company called EPD or Electronic Product Definition and the company's

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[54] *Engineering Automation Report*, February 1995, p. 1
[55] *Engineering Automation Report*, April 1995, p. 5
[56] *Ibid*, p. 11

 

PDM tools were now being sold under the Optegra brand. The marketing of the EDP concept was particularly well done with the focus on what customers were achieving with Computervision's design and data management software rather than on the tools themselves. The company produced several booklets to explain how contemporary technology, when used effectively, could enhance the profitability of manufacturing and engineering organizations.

For a while, business picked up significantly. The company received a $9.4 million order from Hughes Space and Communication for CADDS 5, CAMU and DesignPost software. This was followed by an $8.2 million order from United Defense (the producer of the U.S. Army's Bradley Fighting Vehicle). The most significant order was a $25 million deal with Airbus Industrie, the commercial consortium owned at the time by Aerospatiale, British Aerospace and Daimler-Benz Aerospace. This involved over 1,500 seats of design and data management software. Vickers Shipbuilding and Engineering ordered $11.9 million of software and services and Rover another $9 million over three years. There were also $1 million orders from TVS Suzuki, Jaguar, Nokia and Volvo.

The August 1995 issue of *Engineering Automation Report* contained an update on Computervision's three-part business strategy. The first component of this plan was to continue going after automotive, aerospace and shipbuilding accounts with a combination of CADDS 5 and Optegra PDM software. The second thrust was to pursue the low end CAD market with PELORUS-based design and drafting applications sold through a dealer channel as well as by the company's direct sales force which would sell these low-cost packages in large quantity to major accounts. The third area of interest was to sell PDM solutions (what the company referred to as EDM or Enterprise Data Management) to companies that were using competitive design software. At this point, neither the company nor analysts following the company realized the extent to which PELORUS was a house of cards ready to tumble down. In October, the company hired Ed Wagner, the former president of Boston Communications and vice president of marketing at Rasna to head up what was now being called the PELORUS Business Unit.

Other than PELORUS, the other products the company was pushing in addition to CADDS 5 were Optegra applications such as Configuration Navigator, CAMU and the PVS visualization software. I was particularly impressed by CAMU – "While other companies offer configuration management, workflow and data vault capabilities, no one else has a package similar to CAMU that can work with multiple data formats."[57] Overall, Computervision's financial results were starting to show this renewed energy and focus. For the quarter ending June 30, 1995 the company had revenues of $131 million and earnings of $7.1 million after interest payments on its huge debt. In spite of the fact that the company's non-CAD service revenue was contracting faster than expected, Computervision planned to begin paying off some of this debt by the end of the year. The following quarter, revenues slipped to $125 million while earnings were up to $8 million. In the fourth quarter revenue inched up to $131 million while earnings before special charges were $12.7 million.

Much of this positive sales momentum continued to be in Europe. One example of this was a strategic alliance the company announced with Russia's Tupolev Aviation Company which planned to use CADDS 5, CAMU and Optegra to help design a new

[57] *Engineering Automation Report*, August 1995, p. 1

 

executive jet. In December the company issued an additional 13.8 million shares of stock in a secondary offering and paid off $125 of debt reducing its annual interest payments by $15 million. At about the same time, Kathleen Cote who had been managing the company's service business unit was promoted to president and chief operating officer. The company's stock ended 1995 at $14 per share.

**Trucking along**

As 1995 moved on into 1996, few significant announcements were coming out of Computervision. The company seemed to be focused on basic tasks such as improving its product portfolio as well as beefing up sales around the world. In April 1996, new Optegra modules for handling workflow requirements and standalone data navigation were added to the company's product line. Around the same time, the company announced a large $26 million contract with Peugeot. The significance of this order was that Peugeot was a user of CATIA V4 software as well as CADDS 5. Then in May, the company promoted Salahuddin Kahn to the position of vice president of product development and hired former SDRC vice president Rock Gnatovitch as vice president of marketing.

During 1996, Computervision's overall revenues continued to slide as the company's business of servicing legacy Prime and Computervision hardware dried up. In the second quarter revenues were down to $119 million but the company stayed comfortably in the black with earnings of $10.7 million.

In July 1996, Computervision provided the media with a preview of CADDS 5 Release 6.0 which was scheduled for release in the fall. The key enhancements were an improved three-dimensional sketcher that was capable of working with arbitrary planar surfaces, improved parametric design capabilities including an enhanced ability to edit model history and improved machining operations. The company had been selling a version of DesignView which it had obtained when it acquired Premise in 1991as a two-dimensional sketcher. The problem was it that its integration with CADDS 5 left much to be desired. Release 6.0 was intended to fix this deficiency.

At the same time, *Engineering Automation Report* noted that PELORUS development was "moving slower than expected."[58] In spite of this, functionality such as the three-dimensional sketcher was being implemented to be used by both CADDS 5 and PELORUS. Computervision also announced that it was dropping HOOPS as its graphics engine in favor of internally developed technology, probably because Autodesk now owned Ithaca Software, the developer of HOOPS. The company was focused on increasing its North American sales. The direct sales force totaled 126 people with plans to expand to 150 in the near future.

In September 1996, Computervision decided that its service business was a distraction and that it was time to focus strictly on CAD/CAM software and consulting services. The company agreed to sell its service business to an investment group headed by J. F. Lehman & Company for $125 million. Computervision was to receive $100 million in cash when the deal closed and planned to use those funds to pay down outstanding debt. The cash portion of the purchase agreement was subsequently reduced to $65 million. Computervision hoped to reduce expenses by $20 million per year.

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[58] *Engineering Automation Report*, August 1996, p. 10

 

Two other developments were significant in late 1966. Kathleen Cote became CEO and Russ Planitzer returned to his previous position as non-executive chairman of the board. Computervision also spent $3 million to acquire a small UK software firm, 3rd Angle. Headed by John Stevenson, this company was developing a new mid-range CAD package built around a Parasolid core.

For 1996, Computervision had CAD revenues of $303 million compared to $287 million the year before. Significantly, software license revenue increased by 17% to $192 million. Towards the end of the year the company closed million dollar plus deals with Boeing, Solar Turbines, Volvo and Bath Iron Works. Computervision also signed a joint marketing agreement with EDS which resulted in a $54 million contract to provide software and services to Roll-Royce Aerospace Group and Allison Engine Company. This relationship did not sit very well with the marketing people at EDS Unigraphics and they soon issued a press release downplaying the significance of the EDS/Computervision relationship. EDS and Computervision then issued a joint press release stating that they had signed a ten-year agreement "to pursue defined opportunities for product development solutions in the global aerospace and manufacturing markets."[59]

**The end of the road**

The deal to sell Computervision's service business to J.F. Lehman never took off and was terminated in March 1997. As a fallback position, Computervision signed a non-binding letter of intent to sell 51% of the services business to M. D. Sass Investors Services with the intent of rebranding that portion of the company as Computervision Services International (CVSI) with James Regan as president of CVSI. At this point the company's revenues began to plummet and losses were starting to pile up. For the first quarter of 1997 the company had revenues of $77.8 million and a loss of $33.4 million. The company continued to announce significant contract awards but they were smaller than in prior years - $1.6 million from Westinghouse, $1.1 million from Tupolev Aviation and $1 million from Magneti Marelli in Italy were typical.

In June 1997 I visited Computervision to try to understand where the company was and where it was heading. It was obvious that the failure to sell the services business to J. F. Lehman at an attractive price was a major setback and trying to come up with an alternate strategy absorbed a tremendous amount of management time. The most significant news was the effective termination of the company's highly touted PELORUS project. PELORUS was supposed to result in a new object-oriented development platform for Windows-based design and drafting applications including the surface modeling being developed by Mercedes-Benz. That simply did not happen and what was left of PELORUS was being combined with the software developed by 3rd Angle to form a new mid-range product. The balance of the company's development activity was being focused on integrating Optegra modules using a common user interface, Release 7.0 of CADDS 5 with new interactive surface design technology and porting Medusa 3.0 to Windows NT and re-pricing it in the range of $4,300.

Financial results for the second quarter did not show much improvement. Revenues increased to $88.5 million but the company had a $51.2 million loss after taking a $45 million restructuring charge. By the end of September, the company's stock

[59] *Engineering Automation Report*, December 1996, p. 15

 

was selling for a little more than $2 per share and the company's bonds were selling for 50 cents on the dollar.

In October 1997, Computervision asked me to come to Bedford so they could brief me on a new software packaged they planned to launch at AUTOFACT in early November. The intent was to have an article describing this software, to be called DesignWave, in the November issue of *Engineering Automation Report*. This package was based on the software acquired from 3rd Angle along with some, but not much, PELORUS functionality. It was designed to run on both Windows 95 and Windows NT and it implemented the Windows user interface paradigm. DesignWave handled feature-based solids modeling using a Parasolid geometry core. I thought a new package from the ground up was a better strategy that trying to cram CADDS 5 into a PC. The software had a number of well conceived capabilities and I expected that it would give products such as SolidWorks and Solid Edge a run for their money if it were marketed aggressively.[60]

DesignWave was to be launched on November 4, 1997 at a press conference the morning AUTOFACT opened. With a room full of editors and analysts, Wayne George, the DesignWave marketing manager, strode to the podium and said "And at eight o'clock this morning, Computervision announced that was being acquired by Parametric Technology Corporation." With that statement Computervision ended the press conference leaving everyone in shock. PTC planned to acquire Computervision, subject to shareholder approval, for $490 million, $260 million in stock and the assumption of approximately $230 million of debt. The purchase closed in early 1998. The nearly 30-year history of one of the major companies in the industry thus came to an end.[61]

PTC's plans for Computervision were to slim down its staff by laying off 500 of the then current 1,200 employees and to continue supporting CADDS 5 and Medusa for some indefinite period of time. Long term, they made it very clear that the objective was to encourage these customers to move to Pro/ENGINEER. PTC also planned to build a major account marketing and sales program around Computervision's perceived success in this area. The expectation was that expenses could be cut to $100 million in 1988 while revenues would be in the area of $120 million. These were actually fairly conservative goals. There didn't seem to be much of a future for DesignWave in that PTC management led by CEO Steve Walske did not think much of Windows-based mid-range solutions built around Parasolid.

See Chapter 16 for a discussion of how PTC handled Computervision's CAD products, the surprise discovery a of a gem of a PDM solution called Windchill hidden among the rubble and how key Computervision managers ended up in senior management positions at PTC. Medusa was sold to Germany-based CAD-Schroer in early 2002 and VersaCAD was sold to Archway Systems (see Chapter 20) in October 1999. In 2004 PTC was still generating $30 million in annual sales from prior Computervision and Calma software including about $4 million in new license revenue – mostly CADDS 5 that was being used on long term projects.

**Why did Computervision eventually fail?**

For many years, Computervision had reasonably good products, an aggressive sales force and competent management. So why did the company eventually fail. I

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[60] *Engineering Automation Report*, November 1967, p. 6
[61] *Engineering Automation Report*, December 1997, p. 1

 

believe that there were three primary reasons this occurred. The first was the company's decision in the mid-1970s to build its own computer equipment. While this move initially improved the company's gross margins, it created a mindset that Computervision was a hardware manufacturing company that happened to sell engineering design and drafting software.

When management attention in the late 1970s and early 1980s should have been focused on creating a new generation of solids-based design software, they were distracted by the effort spent on trying to move the company's computer technology into the 32-bit era. Once Computervision decided to use industry-standard workstations and servers, extracting itself from the extensive manufacturing infrastructure it had established proved to be very costly. Computervision was not the only company to face this problem. Auto-trol Technology, Applicon, Gerber, and Intergraph all went through the same exercise and other than Intergraph, none did it successfully.

The second reason the company ended up a shell of its earlier self were the two hostile takeovers, a successful one by Prime and the unsuccessful one by MAI Basic Four. The Prime acquisition might well have worked out successfully if given a chance but just as the company was making progress in melding the Prime and Computervision businesses together it was hit with the unexpected hostile tender offer from Bennett LeBow. I still have a hard time understanding why Prime felt it necessary to bring J. H. Whitney & Company into the picture. LeBow's financing seemed shaky towards the end of the takeover fight and it is entirely possible that if they had waited him out, he may well have just faded into the sunset. But they did not do that and when the dust settled, Prime was saddled with greater debt than the company could handle. From then on, financial issues dominated the management of Prime and then Computervision after its second IPO. The company was never able to get its head above this financial Albatross.

The third problem area was the difficulty customers had in making the transition from CADDS 4X to CADDS 5. When initially released, CADDS 5 had far too many technical problems and many of the applications customers had come to depend upon were only available for use with CADDS 4X. The transition from one to the other was difficult and many customers felt if they were going to go through such a difficult upgrade why not look at alternative products on the market. Those that did frequently ended up buying software from other companies including Autodesk, PTC, SDRC and EDS Unigraphics.

In addition, the money spent on the abortive PELORUS project could have been better spent elsewhere, acquiring Calma may not have been worth management's time and effort and even the acquisition of Cambridge Interactive Systems and Medusa may have been a bad idea. None of these issues, however, were of the magnitude of the other problems described above. Computervision probably even could have survived the transition away from manufacturing its own systems but the financial impact of two hostile takeovers was more than any company could have withstood.

# Chapter 13

# IBM, Lockheed and Dassault Systèmes

## Introduction

This is probably the most complicated chapter in this book in that it involves a number of different companies involved in an overlapping manner over several decades with multiple different products. It does not follow a strictly chronological format very well. Therefore, I have chosen to cover some of the following subjects over longer timeframes rather the chop them up into time-dependent chunks. Also, this is really the story of CADAM and CATIA and not of IBM per se. As a consequence, I have kept the discussion of IBM to the minimum required to put what occurred with these software products into context. Finally, although Dassault Systèmes acquired SolidWorks in 1997, that company and its products are discussed separately in Chapter 18.

## Lockheed's early development of CADAM

CADAM (Computer-graphics Augmented Design and Manufacturing) began as an internal mainframe application referred to as "Project Design" within Lockheed's Burbank, California operation in 1965. It was initially implemented on IBM 360 computers using IBM's 2250 graphics display terminals. From the start, a primary objective was to minimize response time. Working with IBM, the two companies determined that optimum productivity would be achieved if the response time for individual operations could be kept under 0.5 seconds. This was typically accomplished with CADAM although some critics claim that it was done by implementing commands that individually did less than what other systems accomplished with each command. According to these critics, the result was that it took more steps to accomplish a given set of tasks with CADAM than with competitive systems.

One of the first engineers assigned to Project Design was R. Lee Whitney who joined Lockheed-California as an associate engineer in late1965 after a brief stint at Boeing. He went to work for Boeing after receiving a BS in mathematics from Portland State University. He later added an MS in computer science and an MBA while at Lockheed. Whitney represents the most complete repository of information regarding CADAM in that he was associated with this product and MICRO CADAM for over 30 years.

As discussed in Chapter 4, Lockheed's Marietta, Georgia operation had been an early adopter of CAD/CAM technology using a combination of internally developed software and commercial systems. Lockheed California, however, was reluctant to jump on the bandwagon in that the company felt that it would have to develop its own hardware since adequate graphic systems were not yet commercially available. When IBM introduced the 2250 display terminal in April 1964, this attitude changed and planning for an internally developed software system was initiated.

The first IBM computer system dedicated to computer graphics was installed in Burbank in early 1966 and software testing began in April of that year. The configuration consisted of an IBM 360/50 computer with 512KB of memory, a 2250 Model II display, a Model 2314 disk drive and a flatbed plotter. The initial design software (the name CADAM was not used until 1972) was developed by a team of six programmers working under the direction of Harold Bradley. Bradley was also responsible for the company's NC activity and for a group doing lofting work. Within a few months this team had implemented basic design capabilities and was producing test NC parts.

Figure 13.1
Harold Bradley at IBM 2250 Terminal Designing NC Part

According to Whitney, one of most critical decisions the development staff made was to fit the applications they were working on to the computer environment at hand rather than get carried away trying to build the ultimate design and manufacturing solution. Early focus was on supporting Lockheed's proposal to the Federal government to build a supersonic transport. One task was to demonstrate the precision of the software to the FAA. A model of the SST was created that enabled a user to zoom in on an ashtray placed between two seats. When the government decided not to pursue the SST in 1967, one result was a massive layoff at Lockheed California. One of the people laid off was Thurber Moffit, another industry pioneer who was acting as a consultant on this project. The design system programming staff was reduced to just one person, Whitney.[1]

Lockheed started rebuilding the design project staff in late 1967 and soon it was back to a dozen programmers. Outside consultants included MIT's Steven Coons and S.H. (Chase) Chasen from Lockheed's operation in Georgia. Most of the development work was being funded by the Engineering Department at Lockheed.

The mainframe implementation of what eventually became CADAM was forced to live with a number of limitations imposed by the hardware and the time-sharing mode of operation. The latter factor dictated that models had to be kept small, otherwise one or two users working with large models could slow the system down for all the other users.

[1] Interview with Lee Whitney on November 8, 2004

Early IBM graphics terminals such as the 2250 had only 8KB of refresh memory, limiting how much graphics could be displayed at one time. There were also problems with the floating point format IBM was using in the mid-1960s. It was less precise than the alternate IEEE standard and truncated results rather than rounding. Whitney describes a test in which he rotated a 100-inch line 180 degrees in one degree increments. At the end of the test, the line was just 97-inches long.[2] As a result, careful attention was subsequently paid to avoiding numerical accuracy problems.

As mentioned elsewhere, pointing devices such as light pens only react to seeing light on the display's monitor. It was not difficult to select elements such as the end of an existing line but it was very difficult for the user to input a coordinate location in a blank area of the screen. Lockheed handled this problem by flooding the screen with rows of the character "R." The user could indicate a specific location by pointing the light pen at one of these characters. Each row of characters took just one refresh cycle so the user hardly noticed what was being displayed. The programmers called this a "character blast."

**CADAM begins to mature**

Bradley died in 1968 in a mountain climbing accident and was replaced by Jean Lucas. One technical change that resulted was increased use of APT for NC work. Bradley had not been a fan of APT while Lucas favored using it. Even though CADAM was not a three-dimensional system in the classical sense, it did have strong NC capabilities. Fundamentally, the software used a two-and-a-half dimensional technique not unlike the descriptive geometry techniques used by traditional drafters.

The software facilitated the creation of multiple views of an object without the need to use temporary construction lines. Using this methodology, it was possible for a user to design elements such as a pocket with sloping sides and then program a five-axis milling machine to cut the sides of this pocket using an approach called swarf cutting.

From the initial 360/50, the CADAM group were provided with increasingly powerful hardware. In late 1968, the system which was used for both software development and actual engineering design was upgraded to an IBM 360/91, one of the most powerful computers IBM had built up until that time. It had a 2MB memory (less memory than what is required today for a high resolution digital photograph.) and was capable of two MIPS performance. The computer had drum, disk and tape memory and fairly soon was supporting 12 display terminals. CADAM used 128 KB partitions to support each terminal and frequently, the system was running several different engineering applications simultaneously.

Eight of these terminals were located 4,500 feet away from the computer center in the engineering department. This was done using a high-speed data link provided by IBM that incorporated cables placed in a helium-filled conduit. According to Whitney, performance of the remote terminals was comparable to those located adjacent to the computer.[3]

One problem this project had to endure was a high rate of personnel turnover. Whitney states that the first 50 man-years of effort spent on CADAM was done by 50 different people. By 1980 there were about 100 programmers associated with the

[2] Interview with Lee Whitney on November 8, 2004
[3] Interview with Lee Whitney on November 8, 2004

 

project.[4] After the SST was canceled, Lockheed California's focus shifted to a new commercial wide-body airliner, the L-1011. CADAM was used extensively on this project, from lofting airframe surfaces to detailing 75,000 electrical connectors.

Figure 13.2
Terminals located in Lockheed Engineering Department

While engineering had access to CADAM terminals during prime shift, other groups could use them during the swing and graveyard shifts. Over a ten-year period, Lockheed designers using CADAM produced over 400,000 electrical diagrams. At one point, they were producing a revised drawing every 15 minutes. Microfilm was used for released drawings while electrostatic plotters were used for check prints. In 1975, Lockheed was using ten 500-foot rolls of paper each day - the equivalent of a mile of check prints. Frank Puhl (president of CADAM, Inc.) once described to me the effectiveness of CADAM on the L-1011 project. "Walk on the plane an look down. The carpet fits while on other aircraft it tends to bunch up. That is because we used CADAM to design the L-1011 carpeting." A significant shortcoming of CADAM was its lack of any type of macro or user-development language. While the programming staff was able to provided specialized code when requested, this did not provide tools for users to do likewise.

## Commercializing CADAM

By 1971, Lockheed Corporation was beset by a host of problems. The L-1011 was not selling well, the Air Force's C-5A project was suffering huge cost overruns and even the company's engineering subsidiary was having problems. Eventually the federal

[4] Interview with Lee Whitney on November 8, 2004

government had to step in and provide a $250 million loan to Lockheed to keep it afloat. The company looked around for ways to increase its revenue and top management felt that there was a business opportunity in selling its design software.

Engineering was against this move in that it felt that the software provided them a competitive advantage. They were overruled and in 1972 Lockheed set up a separate organization to continue the development and marketing of the software. This was also the point in time when the software was formally named CADAM.

The first and only head of the CADAM organization within Lockheed was Frank Puhl. He was an accountant who was one of the youngest vice presidents the company had had up until that time. By 1972 he was vice president of finance and administration with several thousand people reporting to him including the company's computer organization. Supposedly, he was given the choice of running the CADAM project or taking the lead at a different Lockheed company. He chose CADAM.

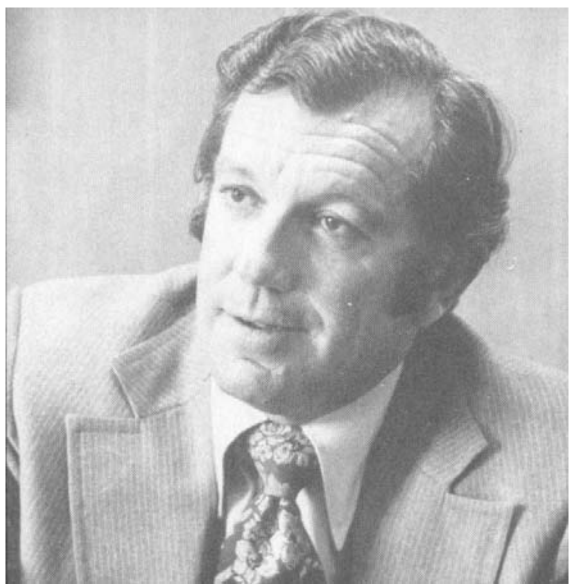

Figure 13.3
Frank Puhl

The first three installations outside of Lockheed California in 1974 were IBM Paris (to facilitate selling CADAM in Europe), Lockheed Missile and Space Corporation in Sunnyvale, California and Lockheed Georgia. This was followed the next year by sales to Northrop, Grumman and Dassault Aviation (Avions Marcel Dassault). Unlike most commercial CAD system vendors, Lockheed provided source code to its customers enabling them to make changes to the software.

Customers were soon reporting significant productivity gains using CADAM. Lockheed Georgia utilized a four-terminal system on a project to produce a stretched C-141 aircraft for the Air Force. The original plan envisioned a maximum staff of nearly 70 people working on the project for a period of 18 months. They were able to do the work with a staff of 40 and they did it in 12 months.

CADAM was an expensive solution and many engineering managers were reluctant to make the investment in the mid-1970s. Gradually, the salaries of engineers increased and the cost of the computer hardware per user came down significantly. By 1976 the economics looked much better and usage took off. At Lockheed California, the number of CADAM terminals in use went from about 40 in 1976 to over 220 in 1980.

During the 1970's the main objectives for CADAM software was to reduce operating costs and increase system reliability. Key elements of CADAM's system interface code (developed by Dick Bennett and John Saunders) became very useful in developing interactive applications, CATIA at Dassault and NCAD at Northrop.

**IBM becomes the primary sales agent for CADAM**

IBM fairly quickly realized that CADAM could help it sell lots of large mainframe computers as well as numerous graphics terminals. In 1978 IBM signed a non-exclusive marketing agreement with Lockheed and set up a sales and support staff to promote CADAM running on IBM computer systems. Lockheed also signed similar agreements with Fujitsu in Japan and Perkin-Elmer, a manufacturer of 32-bit minicomputers. The Fujitsu relationship resulted in a meaningful volume of business, particularly in Japan, but the Perkin-Elmer deal never really got off the ground. In 1982, Lockheed established CADAM, Inc. as a separate company to continue the development and marketing of CADAM.

Several CADAM features characterized the early versions of the software. First and foremost, the software was developed to run on IBM mainframe computers using vector refreshed display terminals. At the time, these terminals had very little local computing capability so most graphic manipulations were done by the host computer itself. Since there was little incentive to make the software machine-independent, only about 75 percent of the code was written in FORTRAN. The balance was done in assembly language which resulted in very fast graphic manipulations. This was one way the Lockheed programmers were able to meet the 0.5 second reaction speed mentioned earlier.

At the time CADAM was being developed, most other CAD systems used Tektronix storage tube graphics displays. While they could display a considerable amount of fine resolution data, images could not be selectively erased. The storage tube had very limited capability to display menu-type information. The IBM and compatible vector refresh displays were more expensive than the storage tube devices but could be selectively erased and images could be moved around. They also could rapidly change lists of menu items. The downside was that they could display a limited amount of data before they became overloaded and started to flicker.

IBM and Lockheed were adamant that, overall, the vector refresh devices were preferred over storage tube displays. The selection of displayed entities was very quick because these terminals used a light-pen as the operator input device. With a light-pen the user could directly select entities rather than requiring the computer to indirectly match a coordinate input from a tablet device to the drawing database. CADAM complemented the light-pen with a 32-button programmable function box. Most CADAM users became proficient in using the combination of keyboard, function box, light-pen and on-screen menus to initiate graphic actions.

CADAM was fundamentally a two-and-a-half-dimension system that enabled drafters to create multiple views of complex objects using traditional manual drafting techniques. This enabled users to quickly prepare isometric drawings from these orthographic views. In addition to production drafting, the software was used to automate NC machine tool programming. CADAM could also be used to compute two-dimensional section properties.

By 1982, Lockheed began shipping a version of CADAM with three-dimensional capabilities. To produce drawings from the model the user created a two-dimensional projection and then manually added dimensions and notes. The software handled a variety of surface types and could be used to create finite element models although the latter task involved a substantial amount of manual intervention. Automatic meshing was off in the future. Lockheed provided several support modules including a Data Management Module for cataloging data files, a Statistical Data and Report Generator that provided system managers with detailed operating statistics such as system response times, an Accounting Information Modules for recording man-hours spent on specific projects and a Geometry Interface Module that provided an interface to the CADAM database for user developed software.

According to the February 1982 issue of *Computer Aided Design Report*, Lockheed had been using the three-dimensional version of CADAM internally for about four years but refused to license it to outside customer in order to protect a perceived competitive advantage. By early 1982, Lockheed had produced 600,000 drawings using CADAM and had about 60,000 of them stored on-line. The system was used to design the F-117 Stealth aircraft (the design of which was shown on a History Channel program) and the Hubble Space telescope. At this time the company was doing about 50 percent of its tool and fixture design work and all its NC programming with CADAM although only about five percent was being done using the software's three-dimensional capabilities.

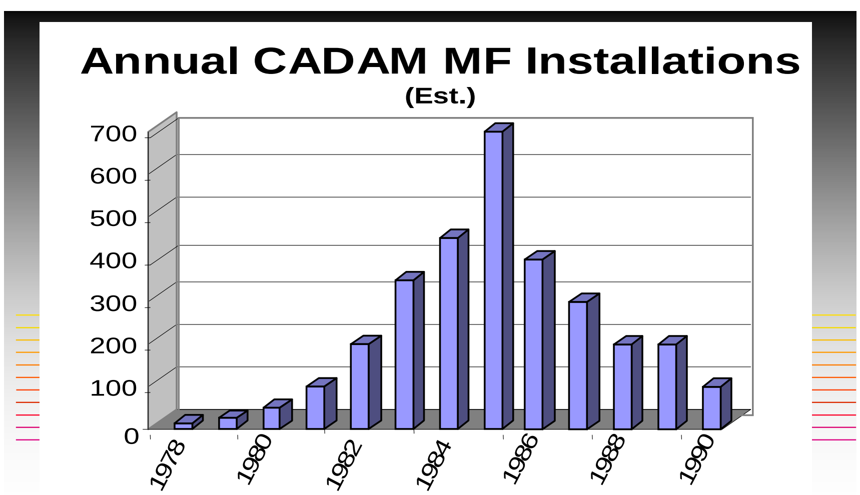


Figure 13.4
Annual Mainframe CADAM Installations[5]

Hardware prices in the 1982 era ranged from about $265,000 for an IBM 4331 Group II computer with two 3251 displays to several million for an IBM 3081 with perhaps 20 or more terminals. A basic CADAM configuration with drafting, data management and hard copy output cost $26,350 plus a monthly fee of $3,200 irrespective

[5] Whitney, Lee, PowerPoint presentation

 

of the size of the IBM mainframe it was being run on. As a consequence, adding additional seats only cost the user the price of the display terminal.

As mentioned earlier, IBM obviously was interested in CADAM because it had the potential to help the company sell a large number of expensive mainframe computers and many thousands of 3250 and 5080 graphics terminals. The earlier chart shows the sale of the mainframe version of CADAM over the years.

Most CADAM training and customer support was provided by Lockheed in that IBM had few trained engineers available to support customers. Interestingly, the largest CADAM customer at this time was IBM itself. IBM used a special version of CADAM that included features that the other 190 customers around the world did not have access to. Eventually, some of these features worked their way into the released version of the software. *Computer Aided Design Report* concluded its review with: "CADAM is not state-of-the-art software, but it is a highly reliable system with a long track record of successful use."[6]

### IBM graphics terminals

In order to understand IBM's mainframe graphics terminals it is necessary to appreciate how these computers were structured in regards to peripheral devices. With the introduction of the System 360 in April 1964, IBM began offering an interface mechanism called a data channel. (There were similar such devices on earlier IBM computers.) This computer module served as the means for transferring data to and from the memory of the computer. To some extent, it was a programmable unit that could be adapted to different input/output devices. Graphic terminals were not connected directly to the data channel. Rather they were interfaced to a display controller that contained the memory and control logic necessary to generate graphic images on the display monitors.

The first generally available IBM display terminal was the 2250 Model I which was introduced with the System 360 in April 1964. The 2250 included a self-contained display and graphics controller. The monitor was a round CRT, 21-inches in diameter, which had a 12-inch square usable area. Resolution was 1024 by 1024. The 2250 was a vector refresh device with display commands stored in the controller's local memory which was either 4,096 or 8,192 8-bit plus parity words. The basic unit could only display short horizontal, vertical or 45-degree lines. An optional line generator was available which could display lines of any length at any angle. This latter device was required for any meaningful graphics applications.

The major drawback of the 2250 was the flickering which occurred when dense graphic images were displayed. Likewise, there was a finite limit on the amount of detail that could be contained in a given image dictated by the size of the controllers memory although subroutine techniques could be used to extend this capacity. An optional character generator increased the display's capacity to some extent. User interaction was by means of a light pen and a function keypad. A fully functional 2250 Model I with line generator, keyboard, function keypad and 8KB memory sold for over $100,000 in 1974.

The 2250 Model I was followed by the 2250 Model III which was driven by the 2840 Model II controller which had a 16,384 18-bit word memory. A maximum of four

[6] *Computer Aided Design Report*, February 1982, Pg. 1

 

2250 Model III displays could be attached to a 2840. This reduced the cost per seat to about $65,000.[7]

Figure 13.5
IBM 2250 Display Connected to an IBM 1130 Computer[8]

Around 1978, IBM signed an agreement with Sanders Associates of Nashua, New Hampshire to manufacture a replacement for the 2250 called the 3250. The 3250 had more display memory and faster line drawing speed resulting in the ability to display more dense images, perhaps as many as 8,000 individual vectors, flicker free.

IBM introduced its first raster display graphics terminal and display controller, the 5080 and 5085 respectively, in late 1983 with deliveries starting in early 1984. Many graphic functions were now performed by the display system, freeing the host computer of these tasks. The 5080 came in both monochromatic and 256-color versions selling for about $22,000 and $28,000 respectively. This unit maintained IBM’s earlier display products’ square 1024 by 1024 resolution at a time when other display manufacturers were beginning to sell units with a rectangular 1280 by 1024 viewing area.

While the 5080, which used a tablet for user interaction rather than a light-pen, could emulate the older 3250, it had many new capabilities that require new software. It would be some time before CADAM and CATIA were upgraded to use features such as the selective erasing individual entities without updating the entire screen.[9]

In January 1986 IBM introduced new 5085 display controllers replacing the older Model 1. The new units, the Model 1A and the Model 2, had 512KB of display memory and greater local processing capabilities. Prices were reduced to $13,300 for the Model 1A and $18,300 for the Model 2.[10] Subsequently the Model 2A was introduced with a 1.5MB memory.

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[7] *The Computer Display Review*, GML Corporation, November 1976
[8] http://www.columbia.edu/acis/history/2250.html
[9] *Computer Aided Design Report*, December 1983, Pg. 8
[10] *Computer Aided Design Report*, February 1986, Pg. 14

By 1989 IBM had shipped over 50,000 5080 graphics terminals. As the price of electronic components and semiconductor memory dropped, IBM was able to increase the performance of these units as well as reduce their cost. In early 1989 the 5086 Graphics Processor replace the earlier 5085 with up to twice the three-dimension display performance and a price of just $11,900 compared to a then current price of $14,200 for 5085 Model 2A.[11]

IBM launched a new high-performance, display system, the 6090, in November 1989. It was similar in concept to the 5080 but offered five to ten times the performance at a substantially higher price. The press release introducing this product claimed that it had twice the performance of the Silicon Graphics 4D/210GTX . Ten floating-point graphics processors could transform one million three-dimensional vectors per second or display shaded images at 40 million pixels per second. Shaded images were produced by an optional processor that supported multiple light sources and depth-cueing. The 6090 also handled industry-standard 1280 by 1024 images rather than the 1024 by 1024 images previous IBM raster displays were limited to.

Prior IBM displays required that the host computer handle much of the display generation that could now be handled by the graphics subsystem. From a performance point of view, the 6090 was one of the first commercial devices that could rotate shaded images in real time. There were two 6090 graphics processor models. A basic 6090 system capable of handling two-dimensional 16-color graphics cost $26,650 while a fully loaded system capable of processing complex shaded images with 16 million colors and equipped with 32 MB of memory sold for $72,150. IBM also introduced new channel control units that could handle up to 192 devices each as compared to the prior unit that could handle 32 5080 class displays.

Unlike the 5080, the 6090 could not be used with the RT PC as described below. It was strictly a mainframe device. At the time of introduction the only software that took advantage of the 6090's new graphics features was SDRC's CAEDS software. It was estimated that it would take up to a year before CADAM and CATIA would fully take advantage of these features.[12]

### Fastdraft and other internally developed CAD systems

Fastdraft was developed by IBM's Boulder, Colorado Laboratory for internal use under the direction of the facility's drafting manager, Ron Giese. After using the software internally for about eight years, the company decided to productize it in late 1982 and began shipping it in May 1983. A Fastdraft system consisted of two 3251 monochromatic vector refresh displays, a model 7361 processor (based on the Series 1 minicomputer), a 29MB disk drive, a floppy disk, an HP plotter (relabeled as an IBM device) and drafting software. The price of the system when introduced was $99,890 or about $50,000 per seat. This was at a time when most turnkey systems sold for over $100,000 per seat.

Fastdraft was a fairly basic drafting system. Perhaps its biggest drawback was the small disk drive which severely limited the number of drawings that could be stored on-line at any one time.[13] Several years later, a revised version of this software was

[11] *Computer Aided Design Report*, March 1989, Pg. 12
[12] *Computer Aided Design Report*, December 1989, Pg. 7
[13] *Computer Aided Design Report*, January 1983, Pg. 9

 

developed by the same lab and sold by Calma as Draftstation. (See Chapter 11). Fastdraft was also sold by Ozalid Corporation, a manufacturer of drawing copier equipment.

In January 1985, IBM reduced the price of a two-station Fastdraft system from $99,000 to $72,900, apparently due to slow sales according to Daratech, Inc.[14] Fastdraft lasted until March 1986 when IBM discontinued it due to slow sales. The product never seemed to have much marketing support within IBM. In reality, Fastdraft probably failed because it was implemented on a minicomputer-based system that was functionally more complete but more expensive than the low cost PCs being used to support competitive packages such as AutoCAD and VersaCAD.

IBM was not about to give up on developing its own CAD package. In August 1986 the company came out with another low cost package, this time for IBM-compatible PCs. Called CADwrite, the software sold for $1,995. Like Fastdraft, it never really took off even though it offered functionality comparable to AutoCAD and VersaCAD at the time. One problem might have been that it only supported IBM's "Enhanced" and "Professional" graphic displays on the PC. These units had 12-inch displays that were too small for serious drafting. Also, IBM never developed a dealer network that could compete with the one Autodesk had established.[15]

In late 1988, the Boulder group tried once again, this time with IBM CAD, a package that sold for just $995. *Computer Aided Design Report* liked the software but commented that IBM had much work to do in establishing a distribution network. The newsletter pointed out that this time IBM had made it easier for dealers to add capabilities to the software and perhaps that would make the difference. On the negative side, this package was hard to learn and had little in common with IBM's mainstream CAD product at the time, CADAM. Like its predecessors, IBM CAD failed to achieve significant market penetration and eventually marketing responsibility was transferred to IBM's CADAM subsidiary in April 1991.[16]

**Alternative CADAM workstations and software solutions**

Throughout the 1970s and 1980s, manufacturers of various peripheral devices such as disk drives, tape drives and printers attempted to capitalize on IBM market dominance by marketing devices that could plug directly into IBM mainframe computers. Called Plug Compatible Manufacturers or PCMs, they were able to undercut IBM's prices by minimizing research and development expenses and operating with lower overhead. One specialty subset of this market was the manufacture of plug compatible graphics terminals. Early leaders in this space were Adage, Vector General and Spectragraphics.

Until it eventually introduced the 5080 color raster display in 1983, customers using IBM graphics terminals were limited to using monochromatic vector-driven displays. Although they had sharp resolution, they would begin to flicker when users tried to display complex drawings. By the early 1980s, color raster technology was becoming more readily available. In June 1982, San Diego-based Spectragraphics began shipping monochromatic and color raster display units called System 1250.

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[14] *Computer Aided Design Report*, February 1985, Pg. 14
[15] *Computer Aided Design Report*, September 1986, Pg. 14
[16] *Computer Aided Design Report*, May 1991, Pg. 16

 

Using typical IBM system architecture, the 1250 consisted of three components, a channel controller that connected to a standard IBM data channel, a display controller and the display itself. Each channel controller supported two display controllers and each display controller supported up to four displays. The 1250 displays had 1024 by 1024 resolution and the color version supported 16 colors.

These units were also capable of functioning remotely. The first unit was somewhat expensive because of all the modules required but average prices went down as more displays were added. A single monochromatic display cost $49,850 while a similar color unit ranged from $79,000 to 89,000 depending upon the amount of memory installed. With the maximum number of displays, costs could be as low as $21,000 per terminal.[17] Spectragraphics subsequently introduced a 16-color raster terminal, the DS 1080, which emulated the 5080 and was priced at $17,900.

A new company, CGX Corporation, announced both vector and raster IBM-compatible displays in October 1982. CGX was founded by two brothers, Ken and John Leavitt in Acton, Massachusetts. John Leavitt had been manager of software development at Adage.[18] The company was able to reduce the cost of its systems by combining the display controller with the display itself. This reduced the cost for small configurations of just one or two terminals. CGX's channel control unit cost $30,000 and supported 16 displays which individually cost $30,000 for monochromatic and $40,000 for color raster. [19]

More than just plug-compatible displays, Vector General announced a complete CADAM system including software and 12 displays for $540,000.[20] Once IBM announced its aggressively priced 5080 color raster display in late 1983, the plug-compatible vendors started coming under increased pricing pressure. Spectragraphics, as an example, reduced the price of its Model 1500 color display terminal from $42,000 to just $22,000 in December 1983.[21]

Adage introduced its first color raster display which emulated the IBM 3250 in August 1983. The 19-inch 4250 had 1280 by 1024 resolution and sold for about $43,000.[22] In January 1985, Adage introduced the Adage Model 6080 raster display which had specifications nearly identical to the IBM 5080. Prices started at $18,000 for a monochromatic unit and $22,000 for a color unit.

Perhaps the most interesting business developing involving display terminals for CADAM and CATIA occurred in September 1986 when Lockheed acquired Sanders Associates, the manufacturer of IBM's 5080 terminals. Sanders also owned California Computer Products (CalComp) which sold a product line of CAD systems as well as the plotters for which it was best known.

CalComp had expanded into the disk drive business in the late 1960s, a move that proved to be financially disastrous. That business was sold piecemeal to several companies including Xerox in 1979 and the rest of the company including the plotter and CAD activities was acquired by Sanders towards the end of 1979. While there was some

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[17] *Computer Aided Design Report*, May 1982, Pg. 11
[18] *A-E-C Automation Newsletter*, April 19831, Pg. 10
[19] *Computer Aided Design Report*, November 1982, Pg. 11
[20] *Computer Aided Design Report*, January 1983, Pg. 15
[21] Author's personal notes
[22] *Computer Aided Design Report*, September 1983, Pg. 12

 

early talk of merging Lockheed's CADAM, Inc. with CalComp after the Sanders acquisition, it never happened.

The most serious clone of CADAM was produced by Adra Systems. Adage was an early financial backer of Adra Systems and in July 1984 Adage introduced the CADstation 2/50 which had been developed by Adra and used command menus and graphical construction techniques similar to CADAM. It sold for $22,000. In January 1986 CADAM, Inc. filed suit against Adage and Adra claiming copyright infringement.

Over time, Adra moved away from proprietary hardware and began supporting its CADAM-like software, now known as Cadra, on a variety of UNIX workstations and IBM-compatible PCs. By 1990, numerous companies such as Sikorsky Aircraft were using Cadra as an alternative to the more expensive CADAM for two-dimensional drafting.[23] As the 1990s progressed, the Cadra become less of a direct clone of CADAM and added features and capabilities conceived by Adra's own developers.

By 1996 there were perhaps 17,000 Cadra seats in use at somewhat over 1,500 customer sites. This was probably the highpoint for the software as the company began to focus on its Matrix PDM software to the extent that the company's name was eventually changed to MatrixOne. The Cadra software was sold in1998 to SofTech which still markets the software. See Chapter 21.

In the late 1980s, the 5080 terminal business went through a period of consolidation. Adage acquired CGX (Jim Norrod, previously vice president of sales at Auto-trol Technology was president of CGX at the time[24]) in 1987 even as it continued to lose money. In August 1988 Adage sold its service business to National Computer Systems (NCS), a vendor of optical scanning systems used by educational institutions. In December 1988, NCS also acquired the service business of VG Systems (formerly Vector General) then in late 1989 NCS acquired the balance of Adage's and VG Systems' graphics business. This basically left two companies in the 5080-compatible business, NCS and Spectragraphics. The world-wide market for 5080-type terminals was about 16,000 units per year and IBM probably had an 80 percent market share.

The days' of graphic terminals connected to mainframes were numbered as the CAD industry switched to networked workstations. Spectragraphics was active in developing hardware and software that enabled systems from Digital, Hewlett-Packard, SGI, Apollo and even IBM to function as 5080 terminals. Although useful in specialized circumstances, this never became a large market. Neither NCS nor Spectragraphics attempted to emulate IBM's new 6090 terminals. NCS eventually disappeared while Spectragraphics managed to stay around. After an aborted attempt to develop workgroup collaboration software, Spectragraphics became a contract electronics manufacturer.[25]

### IBM enters the workstation market

By 1985, it was increasingly apparent that engineering workstations from Apollo, Sun Microsystems, Digital and others were quickly becoming the preferred platform for CAD applications and were going to be serious competition for minicomputers and

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[23] *Computer Aided Design Report*, June 1990, Pg. 14

[24] Norrod became president and CEO of Segway Inc., the manufacturer of the Segway Human Transporter (HT) in March 2005

[25] *Computer Aided Design Report*, June 1990, Pg. 5

 

mainframes in this market space. IBM had long been rumored to be developing a competitive product and eventually introduced the RT-PC in January 1986.

The RT-PC used a new microprocessor architecture called RISC(Reduced Instruction Set Computer) that significantly reduced the number of machine language instructions the computer supported. The IBM RISC processor supported 118 instructions compared to the 304 supported by Digital's VAX systems. Each RISC instruction was less complex than traditional instructions but could typically be executed much faster. While it might take more instructions to accomplish a given task, the expectation was that the total time would be less. This was a debate that would go on for the next several decades. (The RT stood for **R**educed instruction set computer **T**echnology.)

The RT processor was a true 32-bit device with a 32-bit memory bus and 32-bit registers. Virtual memory (40-bit) was managed by a program called the Virtual Resource Manager providing access to a potential terabyte of data. There were four RT models announced at introduction ranging in price from $11,700 to $19,510. In addition customers had to pay an additional $3,500 for AIX (Advanced Interactive Executive), IBM's implementation of AT&T's UNIX operating system.

Half a dozen graphics options were available for use with the RT but only one, the existing 5080, was really applicable for CAD applications. A floating-point co-processor was also available for $1,995. See Figure 13.6. By the time it was all added up, A RT-PC configured for CAD applications (a 6150 Model A25 with floating point processor, 4MB of memory, AIX and a 5080 display subsystem with a 19-inch color monitor) cost about $45,000 without any application software. Although the RT-PC had about twice the performance of a PC AT, it was priced far more than twice as much.

Figure 13.6
IBM RT-PC with 5080 Display

The major problem for the RT was that it was slow compared to competitive systems. In one comparison in *Computer Aided Design Report*, Digital's Microvax II was twice as fast and only cost 38 percent more.[26] Except for the 5080, RT graphics were fairly weak compared to competitive products. While the RT was scheduled for March 1986 delivery, some capabilities were not expected until September. Meanwhile, companies such as Sun and Apollo were expected to introduce new higher performance systems at probably lower prices. According to Dave Burdick who was with Dataquest at the time; "It's a good start for IBM, but they've got a long way to go."[27]

RT-PC sales started off slowly due to a lack of application software as well as price and performance problems. In September 1986 IBM dropped prices by 20 to 32 percent and beefed up the machine's performance. Maximum memory was increased to 8MB, bigger and faster, although quite expensive, disk drives were added to the product line and a new floating-point accelerator that was three times faster than the initial unit was made available. By comparison, an Apollo DN3000 offered 30 percent more performance at 20 percent lower cost.[28]

A year later, in February 1987, IBM announced a faster version of the RT-PC. It used a 10 megahertz processor, either a Motorola 68881 math coprocessor or an optional floating point card, a compact 5080 graphics adapter called the Megapel that was less expensive than the previous 5080 adapter and support for new graphics system software. The new RT was about a match for the Apollo DN3000 in both price and performance. The product continued to struggle, however, and software vendors started to give up on it. The major problem was IBM would move a step ahead in performance and the competition would take a much bigger jump. In January 1988, Autodesk announced that AutoCAD would no longer be supported on this platform.

Although IBM was trying to develop a viable workstation product line and CADAM had been ported to UNIX workstations, IBM was still committed to "big iron" mainframes. As late as November 1989, the company stated that mainframes would be a key platform for at least another decade, especially in situations where they were needed for controlling large libraries of engineering data.[29]

**RS/6000 puts new life in IBM's workstation operation**

The RT never gained much market share and it was not until IBM introduced its successor, the RS/6000, on February 15, 1990 that IBM offered a competitive product in this space. When IBM wants to get serious about a particular market it can get very serious and it apparently decided at some point to get serious about the UNIX workstation market. The RS/6000, when introduced, consisted of a number of graphic workstations and servers built around a nine-chip processor running at 20 to 30 MHz. The RS/6000 was not just an improved RT-PC, it was a totally new design with a new instruction set, a new memory bus design, a new I/O bus and new graphics adapters. Although it was still classified as a RISC design, the processor supported 184 different instructions compared to the 118 in the RT-PC.

The product line incorporated a number of monochromatic and color display processors with 1280 by 1024 resolution. These were a match for anything then being sold by competitors. Typical graphic workstations ranged in price from $19,300 for a

[26] *Computer Aided Design Report*, February 1986, Pg. 4
[27] *Computer Aided Design Report*, February 1986, Pg. 6
[28] *Computer Aided Design Report*, October 1986, Pg. 14
[29] *Computer Aided Design Report*, December 1989, Pg. 3

RS/6000-320 to $104,705 for a RS/6000-730. Overall, the RS/6000 leapfrogged the performance of competitive products offered at comparable prices. In November 1990 the company introduced the model 550 which was rated at 23 MFLOPS and priced at $130,000 with no graphics. It was apparently intended to be a compute server.

Software-wise, IBM used the introduction of the RS/6000 product line to commit to industry standard software. It adopted MIT's X-Windows graphical user interface environment as well as graPHIGS and SGI's Graphics Language (GL) for application development. It was later in 1990 before either IBM applications such as CADAM and CATIA or third party applications such as Pro/ENGINEER, PDA PATRAN or MCS Anvil 5000 were available on this platform.

The version of CATIA introduced to run on the RS/6000 in December 1990 required an IBM 5086 graphics terminal in order to function – costly, awkward and with less than impressive performance. The result was that CATIA shaded images took several minutes to generate and were not particularly smooth. The problem was that CATIA had been implemented using low-level graphic primitives in order to achieve good 5080-series performance. Rewriting this software using graPHIGS was taking more time than customers who wanted to switch to the RS/6000 were happy with. A CATIA system, including a RS/6000 and 5086 terminal, cost over $90,000, probably twice as much as Pro/ENGINEER on a Sun SPARCstation. One result of this was that IBM continued to sell mainframe based CATIA systems for some time after the RS/6000 was introduced.

A new line of graphic interfaces for the RS/6000 were introduced in the fall of 1991. The Gt3, Gt4 and Gt4x offered two-dimensional and three-dimensional capabilities at prices that ranged from $3,500 to $17,000. In 1992 IBM renamed this activity the Advanced Workstations and Systems Division (AWSD). In the fall of that year the company introduced a new high-end workstation, the POWERstation 580 which for a period of time was the fastest UNIX workstation available. It was one of the first workstations that could support 1GB of main memory. The 580s were fairly expensive units starting at nearly $70,000 for the monochromatic model.

IBM was very blunt that it intended to increase its share of the UNIX workstation market from about two percent in 1989 to 30 percent of a much larger market by 1993.[30] By early 1993, the company was offering RS/6000 systems ranging from less than $4,000 to supercomputers capable of 8 GFLOPS performance. Fourteen years later, RS/6000 servers are still a part of IBM's product line although graphic workstations have been superceded by high performance PCs.

### IBM supports the PowerPC as an alternative to Intel microprocessors

In the early 1990s, Intel was taking on an increasingly dominating role as the vendor of choice for PC microprocessors. In late 1991, IBM agreed to work with Apple Computer and Motorola in the development of a new microprocessor called the PowerPC. The development operation, called Somerset, was based in Austin, Texas. The PowerPC used the RISC architecture of IBM's Power processor used in the RS/6000 product line and Motorola's 88000 bus architecture.

The three companies were also working on developing a new object-oriented operating system called Taligent and new multimedia technology called Kaleida. Overall, the objective seemed to be to develop PC product lines at Apple and IBM that would not

[30] *Computer Aided Design Report*, March 1990, Pg. 1

 

be dependent on either Intel or Microsoft technology. The PowerPC never had any significant impact on the PC industry although it was used extensively by Apple.

IBM tried to market PowerPC-based PCs but soon gave it up as a hopeless cause. Eventually the PowerPC was relegated to powering RS/6000 workstations and servers. Even before the PowerPC began shipping IBM was already working on a next generation version. Referred to as the Power Plus, it was expected to double the number of instructions executed each clock cycle. Taligent never got off the ground nor did Kaleida.

The initial PowerPC microprocessor was the 601. It had about the same performance as a 66-MHz Pentium chip but cost roughly half as much. It was also physically smaller and generated less heat. In the fall of 1993 IBM introduced its first workstations based on the PowerPC. Called the POWERstation 25T it started at $9,395 for a unit with a 17-inch color monitor. Overall, performance was comparable to similar systems sold by Hewlett-Packard and Sun Microsystems.

IBM did not give up on its own processor architecture just yet. Shortly after the first POWERstation was introduced, IBM announced a new high-performance POWER2 processor (actually a set of eight chips rather than a single monolithic microprocessor.) and several servers using it. These were given the POWERserver name.[31] Eventually, IBM would switch much of the RS/6000 product line to PowerPC microprocessors. Other than for Apple PCs, this microprocessor never caught on in the PC market space and IBM eventually dropped support of PCs using the PowerPC chip.

In mid-1994 the PowerPC and POWER2 systems were split between groups within IBM targeting end users and large systems buyers. Low cost POWERstations were lumped in with PC products as part of the IBM Personal Computer Company while the Advanced Workstation and Systems Division was renamed the not very creative RISC System/6000 Division and imbedded in the Large Systems Division. Shortly thereafter IBM announced a number of new workstations and servers using both the PowerPC and the POWER2 processors. In addition, the company announced that it would sell high-end Evans & Sutherland Freedom Series graphics for automotive styling and industrial design. These latter systems sold for over $100,000 each.

As time progressed, IBM introduced additional POWER2-based workstations and servers. In early 1995, a 67-MHz POWER2 processor was launched capable of 130 SPECint92 and 267 SPECfp92 performance. The floating point performance was particularly impressive considering the growing use of complex solids models. A RS/6000 Model 3CT with 64MB of main memory, a 1GB disk, a GXT150M graphics accelerator and a 17-inch color display had a list price of $38,795.

### Professional CADAM introduced

Until early 1986, CADAM had strictly been a mainframe-based application running on large IBM computers. The introduction of the PC-RT provided CADAM, Inc. with the opportunity to implement the software on workstation class machines, especially those running some version of UNIX. Professional CADAM was launched in parallel with the introduction of the PC-RT. Priced at $16,000 per copy for the software, Professional CADAM was definitely not expected to be competition for Autodesk's AutoCAD. The software only worked with the version of the PC-RT equipped with a 5080 display. Total system prices ranged from $50,000 for a system with a 15-inch

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[31] *Engineering Automation Report*, November 1993, Pg. 3

 

monochromatic display to $67,000 for a system with a top-of-the-line 19-inch color display.

Professional CADAM was not simply a port of the mainframe CADAM software to the PC-RT platform. Much of the software was actually rewritten for this new offering. The data structure of the two programs were different and a translation program was required to move data files from one machine type to the other. Professional CADAM actually had several significant enhancements compared to the original CADAM software.

- It could handle unlimited size models while CADAM models were limited to about 20,000 words (about 120KB).
- Graphic entities were double precision compared to the single precision format used in CADAM.
- Professional CADAM supported an unlimited number of views compared to the 64 in CADAM.

A system manager could set Professional CADAM to limit model size and utilize single precision so that models would be compatible with mainframe CADAM. While Professional CADAM had the enhancements described above compared to the mainframe version of the software, it also had several limitations. The initial version Professional CADAM was strictly a two-dimensional design and drafting solution with no surface geometry capabilities. There also were no NC or analysis modules available.

According to *Computer Aided Design Report* the pre-release version of Professional CADAM it evaluated was slow, taking 30 seconds to zoom into a 50,000-word drawing file. Delivery was not expected until September 1986.[32]

**CADAM, Inc. launches MICRO CADAM**

In 1984 Lockheed established a joint venture in Japan with Kawasaki Heavy Industries called CADAM Systems Company (CSC). The initial purpose of this joint venture was the marketing and support of CADAM in Japan. CSC realized that there was a need for a low cost version of CADAM and began to develop MICRO CADAM on the PS/5500 personal computer which IBM sold in Japan and was quite different from the PCs sold in the United States and elsewhere. This software was launched in Japan in 1985. A PC/AT version for sale in the United States and elsewhere around the world was introduced the following year. The PC/AT version was typically referred to as the International version.

Although the International version used many of the same menu commands as the mainframe version of CADAM, it was essentially new software. The International version of MICRO CADAM was designed to work on PC/ATs equipped with either IBM's "Professional", "Enhanced" or "3270 PC/GX" displays. Popular display systems such as the graphics cards produced by Hercules were not supported. The required configuration included a hard disk drive, a math co-processor and 640KB of memory as well as a function box similar to that used with CADAM.

MICRO CADAM software plus a special purpose function box was priced at $8,000. Initially it was stated that this package would be sold directly by CADAM, Inc. Shortly thereafter, IBM announced that it would also sell MICRO CADAM.[33] Sales took

[32] *Computer Aided Design Report*, February 1986, Pg. 6
[33] *Computer Aided Design Report*, July 1986, Pg. 16

 

off rather slowly due to the high price, somewhat poor performance and the limited range of hardware supported. In what was probably a major mistake, IBM decided that MICRO CADAM would only be sold by its direct sales staff and not by its PC dealers, many of whom were probably already selling AutoCAD.

At about the same time CSC introduced MICRO CADAM, McDonnell Douglas introduced Crossroads CAD and Intergraph acquired a 50 percent interest in CNR Research, the developer of an IGDS knockoff called C-CAD. With three major firms jumping into the PC CAD market, *Computer Aided Design Report* thought AutoCAD's days were numbered. "Back when AutoCAD was the only game on the PC, we could understand why people bought it. But now that most of the big guys are offering "starter kits" for prices near AutoCAD's there seems little need for AutoCAD anymore." Steve Wolf was often a very insightful prognosticator during his many years of editing his newsletter, but this was not one of those moments.

The summer of 1986 also saw CADAM, Inc. run into some financial problems for the first time as sales during the first five months of the year failed to grow as fast as expected. As a result, the company laid off 53 employees even though it was still hiring specialist such as programmers familiar with solids modeling.

MICRO CADAM was slow to take off, most likely because of its $8,000 price tag. To accelerate penetration of the PC CAD market, CADAM, Inc. introduced a new lower-priced package called Cornerstone. At $2,995 it was competitive with packages such as AutoCAD, Computervision's Microdraft and MCS' Anvil 100MD. Cornerstone did away with the special function box used with MICRO CADAM and mainframe CADAM. Also, data files could not be exchanged with the more expensive versions of CADAM. Obviously, the company was torn between establishing a position in the rapidly expanding PC CAD market and protecting its higher priced products.

In 1988, Cornerstone became MICRO CADAM Plus priced at $3,995. MICRO CADAM Plus used Pharlap memory extension software to get around the 640KB limitation of Microsoft's DOS operating system. It took nearly 18 months to get a relatively bug-free version of the software.[34] A low cost data management option, MC*EDM was launched in mid-1989 at just $295 per seat.

**IBM becomes major player in CAD industry**

Between 1979 and 1985 the CAD industry grew from $340 million to $3.5 billion according to Daratech.[35] During this six year period, IBM's share went from 8.8 percent to an industry leading 21.3 percent. The latter number meant that IBM's CAD-related sales totaled nearly $750 million in 1985. What the reader needs to clearly keep in mind is that during those years, the revenue numbers reported by market research firms such as Daratech included computer hardware as well as software whereas today's numbers mostly reflect just software and services. When IBM sold a $1.2 million CAD system, it probably reflected $1 million for a 4381 computer and 16 graphic terminals and just $200,000 for the CADAM software this system supported.[36] This relationship between hardware and software was comparable to what other turnkey systems vendors charged.

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[34] *Computer Aided Design Report*, May 1990, Pg. 15
[35] *Computer Aided Design Report*, April 1986, Pg. 1
[36] Author's personal notes

There was a serious flaw, however, in how the market research companies reported industry statistics. Basically, companies reported their revenue data to companies such as Daratech. For those companies that were publicly traded such as Computervision and Auto-trol Technology it was easy to compare the numbers provided to market research firms with the firms' published financial reports. Since virtually all these companies' revenue was related to the CAD industry, the numbers were quite accurate.

For computer manufacturers such as IBM, Prime Computer and Control Data the situation was quite different in two regards. Because the CAD system business was a minor part of their overall revenue, it was not possible to confirm the industry numbers they reported with public financial reports and they had many reasons to see the CAD-related numbers as large as possible. The other problem was when the sold a large computer system, perhaps for $1 million or more, they often reported the entire sale as CAD-related even if only a small portion of the computer was being used to run CAD software. Many industry insiders viewed the numbers reported by the computer manufacturers with some skepticism.

By early 1986 the CAD industry was undergoing several structural changes. As reported in an excellent *Computer Aided Design Report* article on IBM in April 1986 Charles Foundyller, the president of Daratech is quoted as stating that: "The rise of IBM is part of a larger trend benefiting general-purpose computer builders at the expense of turnkey systems." As the use of CAD increased, corporate information technology managers began to exert their influence over purchase decisions. Typically, they were comfortable dealing with IBM and if that company offered a reasonable solution that satisfied the basic needs of the engineering department they would push for an IBM decision. In many situations top engineering managers were happy to have IT personnel take over the responsibility for purchasing and maintaining these systems. That way, they could concentrate on their primary mission, designing products. Foundyller went on to state that "The end of the turnkey CAD/CAM business is now in sight."[37]

IBM in the mid-1980s was a company struggling to meet the challenges of a rapidly changing computer industry. It was not unusual for the company to have several different divisions develop similar products on the expectation that the best product would eventually win out. Since IBM was such as major player in the computer industry, it often ended up being its own competitor. As an example, two groups were responsible for promoting the sale of CAD systems, an Engineering/Scientific Market Development group under Robert Tiel and a CAD/CAM Marketing Support group under Dick Burkley and then Mike Corse. Burkley subsequently went to work for Auto-trol Technology.

E/S MD was the organization that identified the software needed to compete in this market and managed the relationship with developers such as Lockheed's CADAM, Inc. CAD/CAM Marketing Support provided the technical field support for CAD sales. While these two groups were pushing the sale of IBM CAD systems another organization, the National Distribution Division, was encouraging other companies to offer IBM systems as part of their CAD offering. That is how the company ended up with vendors such as McAuto and Computervision offering IBM computers running their software in competition with IBM selling the same computers running CADAM or CATIA.

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[37] *Computer Aided Design Report*, April 1986, Pg. 1

At this point in time, IBM had three computer product lines applicable to engineering and scientific users.

- Mainframe “host” computers such as the 3090 and 4300 series which ran IBM proprietary operating systems.
- Stand-alone 32-bit computers such as the recently announced RT/ PC which ran AIX, IBM’s implementation of UNIX. The RT was IBM’s first implementation of RISC technology. For graphics applications the RT was equipped with IBM’s 5080 graphics terminal.
- Personal computers including the PC/AT which ran Microsoft’s DOS operating system.

While each of these systems was manufactured by a different IBM division, E/S MD had as an objective to create software, what it called “user services,” that would hide operating system functions behind a common user interface. Tasks such as finding and copying files would be more consistent and users would be able to exchange files via a common network, especially between UNIX systems and IBM’s own SNA (System Network Architecture) networks. The latter capability was handled by DCS (Data Communication Services). IBM also launched a program called GDQF (Graphical Display Query Facility) for displaying graphical files on dumb terminals.

Around this same time, IBM began promoting the use of PHIGS (Programmers Hierarchical Interactive Graphics Standard) as a cross-platform device-independent graphics standard for three-dimensional applications. Although PHIGS was a well-respected standard and is still offered by IBM on several systems, it never became the vehicle for platform independent applications its proponents expected.

Graphics terminals, which were such a key element of CAD systems were designed and produced by another group, Engineering Systems Products. The company was still offering the 3250 vector refresh terminal as well as the newer 5080 raster terminals. Both monochromatic and color versions of the latter were being marketed. Bob Blumberg, the president of Spectragraphics, estimated that IBM sold between 75 and 80 percent of the 5080-compatible displays while the plug-compatible vendors sold the balance. Where relatively small quantities of display terminals were required, the non-IBM vendors offered comparable performance at lower prices. When a large customer was involved, IBM’s quantity discounts often offset these price advantages.[38]

The bulk of IBM’s CAD business involved the sale of CADAM although Dassault’s CATIA was starting to take on increased importance. As described in Chapter 17, IBM continued to sell SDRC’s I-DEAS software as CAEDS. In late 1993, IBM began to sell the SDRC software under the I-DEAS name, recognizing the I-DEAS Master Series had brand recognition of its own that IBM needed to take advantage of. Compared to its other software products in this area, IBM never sold a substantial volume of SDRC software and one wonders if the marketing resources would have been better spent promoting CADAM and CATIA more aggressively.

By this point in time, it was already apparent that CADAM, Inc. and Dassault Systemes were on a collision course. CADAM was being extended to include three-dimension surfaces while drafting capabilities were being added to CATIA.

[38] *Computer Aided Design Report*, April 1986, Pg. 8

**CATIA provides alternative to CADAM**

Dassault Aviation of France first became seriously interested in applying computer technology to aircraft design in the late 1960s. One of its first efforts using interactive graphics was an internally developed application for smoothing graph data. In 1974, the company was one of the first licensees of Lockheed's CADAM software which it used for two-dimensional drafting work. Dassault recognized fairly early that there would be significant benefits in applying interactive graphics to manufacturing applications. The first such internally developed project was called the DRAPO (Définition et Réalisation d'Avions Par Ordinateur) program. It entered industrial service at the end of 1975.

In 1978, Jean Cabrière, Dassault Aviation's managing director, called for the development of a three- dimensional design tool. A new DRAPO system program, called CATI (Conception Assistée Tridimensionnelle Interactive) was developed by the company's CAD Department. It was initially used to machine complex parts such as wind tunnel models, working from outline drawings defined with DRAPO. With CATI it was possible to design and machine a first wind tunnel wing in four weeks instead of the six months it previously took. In 1981, CATI was renamed CATIA (Conception Assistée Tridimensionnelle Inter Active or Computer-Aided Three-Dimensional Interactive Application in English). This computer program made it possible reduce cycle times, improve quality and optimize production efficiencies.

Some of the underlying work on what eventually became CATIA started in 1960 at Renault where the mathematician Pierre Bezier developed a series of mathematical techniques for describing the curved surfaces of automobile bodies. Bezier's work led to the eventual development of the widely used Bezier Curves for describing mathematical surfaces. In 1976, Dassault Aviation acquired the technology, then known as UNISURF, from Renault for in-house use to complement its CADAM system.

Over the next several years, Dassault programmers under the direction of Francis Bernard expanded this software into a three-dimensional modeler that worked with the more limited CADAM software. The desire was to be able to create surfaces that could then be machined with a minimum of operator intervention. This was especially important in the aircraft industry for rapidly making wind tunnel models.

Bernard subsequently convinced the aircraft manufacturer to commercialize CATIA and to establish a separate subsidiary, Dassault Systemes, on June 5, 1981 to further develop and market this software. Although Dassault Systemes has sold some CATIA directly, the bulk of the sales activity for this product has been handled by IBM since 1982.

Initially, IBM was comfortable handling both CADAM and CATIA since they incorporated different capabilities. CATIA was intended to be used for complex modeling applications and the machining of surface geometry. The production of engineering drawings was still done with CADAM. As described earlier, the typical IBM mainframe could handle a large number of CADAM terminals. That was not the case with CATIA. In the early 1980s CATIA required about four times the computational power of CADAM. CATIA also required an alphanumeric display in addition to the graphics display used for CADAM.[39]

[39] *Computer Aided Design Report*, October 1983, Pg. 7

 

In the 1984 time frame, a major debate took place within IBM over whether to promote the three-dimensional version of CADAM or to switch the company's marketing focus and put its resources behind the newer CATIA software. Eventually, CATIA won out, but not immediately. It was well known that CADAM, Inc. had developed a three-dimensional version of CADAM in the early 1980s but it was late 1984 before IBM agreed to market the software as CADAM Version 20.0. Meanwhile, Dassault was adding drafting capabilities to CATIA in Version 2 Release 1.0.

By 1987, the two packages were in direct competition with each other. The July 1987 issue of *Computer Aided Design Report* led off an excellent review of CATIA with "There's a major battle looming in the high priced CAD/CAM world between Lockheed Corporation's CADAM subsidiary and Dassault Systems, a division of Dassault Aircraft of France. The prize will be the leadership of IBM's CAD/CAM software line."[40] The surprise was how quickly Dassault became the dominating vendor in this market space, eventually swallowing up CADAM and spitting out the pieces like watermelon seeds.

By 1987, CATIA's surface modeling capabilities were as good as those of any other CAD vendor. As an example, the software could blend fillets of unequal radius, a task not many competitive products could handle. All data was stored in a double precision floating point format. CATIA also incorporated a faceted solid modeler. Once the precision of the facets were defined, they could not be changed. Competitive modelers such as Matra Datavision's Euclid allowed designers to use a coarse model during conceptual design and switch to smaller facets for visual representation or NC tape preparation. With this limitation, CATIA could bring a large IBM mainframe to its knees with just a few users working on fairly small models if they defined fine resolution facets.[41]

Typically, CATIA users built fairly coarse models for design studies. When they transitioned to detailed design, these solid models were converted to surface defined models using an operator-directed interactive procedure. It was time-consuming and rather awkward, but it worked. CATIA also provided excellent NC software capable of generating tool paths across multiple surfaces in a single pass. Unlike most other CAM packages, CATIA NC generated an APT source file that was then processed, typically by a mainframe APT program, to generate actual tooling commands. Other applications included electrical schematic drafting, robotic programming and piping design. The latter was not a process plant design package but it did lay the groundwork for moving in that direction.

Although there were far more CADAM installations than CATIA installations, the later was growing rapidly while new CADAM sales seemed to be stalled. New CATIA customers were either replacing legacy turnkey systems or were CADAM users who wanted more advanced modeling capabilities. Perhaps the most significant convert in the 1987 time frame was Boeing Commercial Airplane Company which switched from VAX-based Intergraph systems to mainframe CATIA to support development of the 7J7 aircraft, what eventually became known as the Boeing 777.[42]

By the end of 1988, IBM had installed 1,100 mainframe CATIA systems worldwide. Dassault introduced a RT-PC version of CATIA that was priced around

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[40] *Computer Aided Design Report*, July 1987, Pg. 1
[41] *Computer Aided Design Report*, October 1986, Pg. 12
[42] *Computer Aided Design Report*, July 1987, Pg. 1

$60,000 per seat. It supposedly used the same source code as the mainframe version of CATIA. This never became a popular product.

**Lockheed offers CADAM on non-IBM platforms**

Since it first started selling CADAM through the IBM sales force, CADAM, Inc. had only supported IBM computer systems, at least in public. Beginning around 1985, the company's software developers began experimenting with a UNIX version of CADAM and the company had occasionally shown this software running on Apollo workstations to potential prospects. This was not a particularly well kept secret.

At the 1988 AUTOFACT conference, CADAM, Inc. had its own booth and demonstrated Professional CADAM on a SPARC-based Sun 4 workstation. Then in February 1989, the company announced that it would begin selling Professional CADAM unbundled on both Sun and Apollo workstations for $10,000 per copy. In addition, a program for accessing the CADAM database, CADAM Access, was also available for $2,000 per copy. The company's PRANCE electronic design software was also offered on these workstations as well as CADEX, a schematic drafting and wire list generation program.[43]

Once IBM acquired CADAM, Inc. as described below, the company announced that it would now longer support Sun and Hewlett-Packard (new owner of Apollo) UNIX workstations although this did not happen immediately. The reason eventually given was that since CADAM, Inc. was an IBM company it could no longer sign non-disclosure agreements with other computer manufacturers and that this prevented them from supporting new systems until they were fully announced products.[44]

This was not absolute, however. EDS, which had tentatively selected CADAM along with Unigraphics as the preferred CAD solutions for General Motor's $C^4$ program, announced in May 1990 that it would continue to sell CADAM on Sun and HP platforms both within and outside GM.[45]

**Expanding CADAM's PC product line with P-CAD**

In February 1989, CADAM, Inc. acquired Personal CAD Systems, a developer of electronic design software running on IBM-compatible PCs. P-CAD had been founded by Doug Stone who continued as president after the acquisition. About 11,000 copies of P-CAD's Master Designer II software, a printed circuit board design package, had been sold at the time of the acquisition. In addition to expanding its market reach more into the electronics arena, CADAM was also interested in the fact that P-CAD had developed a domestic dealer network. Up to this point, CADAM, Inc. had been relatively successful in selling MICRO CADAM through IBM's sales force and in Japan through CADAM Systems Company. Sales in the United States through independent dealers had been disappointing, however.[46]

In 1988, P-CAD agreed to sell an automatic PCB router from Router Solutions called Superoute under the brand label of "Rip-up-Router." By mid -1989, the relationship between the two companies had deteriorated, primarily because P-CAD had

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[43] *Computer Aided Design Report*, March 1989, Pg. 14
[44] *Computer Aided Design Report*, April 1990, Pg. 16
[45] *Computer Aided Design Report*, June 1990, Pg. 16
[46] *Computer Aided Design Report*, February 1989, Pg. 9

failed to meet its contractual obligation to sell a specific volume of Superoute. Lawsuits soon followed. After its acquisition by CADAM, Inc. P-CAD switched to an internally developed router called "Rip-N-Route."

**CADAM developments in the late 1980s**

CADAM, Inc. introduced its Interactive Solid Design module in 1987. Called "Interactive Solid Design" or ISD, this software was derived from MAGI's Synthavision package and supported ray traced shaded models which were of high quality but consumed considerable amounts of computing resources. While ISD was a separate program, it was capable of exchanging data with the two-dimensional CADAM software.

Assemblies were created by overlaying individual part models. These assembly definitions could then be saved, something CATIA was not yet able to do. Although CADAM introduced three-dimensional geometry with Release 20 in 1985, it took the company until late 1987 to introduce surface NC milling. This latter package was called NC II and it produced a cutter location file rather than the APT source that CATIA generated.[47]

**Lockheed decides to sell CADAM, Inc.**

Lockheed always seemed to be on the edge of financial disaster. In 1971 it took a federal government $250 million bailout to keep the company afloat. In 1982 the company cancelled the L-1011 wide-body commercial aircraft and took a $300 million write-off leaving it perilously close to bankruptcy once again. By early 1989 the company was grappling with a hostile takeover bid by Harold Simmons, often described as a corporate raider.

As one step in turning itself into a leaner and more financially solvent company, Lockheed announced publicly in April 1989 that it was interested in sell both its CADAM and CalComp subsidiaries. CADAM was no longer a strategic tool at Lockheed in that the company was now using CATIA and SDRC software for its advanced projects. By fall, rumors were that IBM, Fujitsu and SDRC along with a group of venture capitalists were looking at buying CADAM, Inc.

Fujitsu was considered a prime candidate to acquire CADAM, Inc. since it built IBM-compatible mainframes and CADAM was selling very well in Japan. Everyone perceived this to be a threat to IBM's position in this market and on November 9, 1989, IBM announced that it intended to acquire CADAM, Inc. from Lockheed. The plan was to have CADAM, Inc. operate as a wholly owned IBM subsidiary with its employees CADAM, Inc. employees rather than IBM employees. Frank Puhl, the president of CADAM, Inc. retained this position with IBM, reporting to Edward Kfoury, IBM vice president of industrial sector marketing.

IBM paid approximately $100 million for CADAM, Inc., about $80 million in cash and the balance in "non-cash" consideration. This was about one time the company's revenue. Considering that a large part of IBM's $1.35 billion of total system revenue from the CAD market came from selling or leasing hardware in support of CADAM, this was probably a wise investment.

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[47] *Computer Aided Design Report*, November 1987, Pg. 11

 

What it did do, however, was confuse the issue over what would be the preferred CAD system of the future – CADAM or CATIA, especially as user requirements were increasingly shifting to three-dimensional modeling versus two-dimensional drafting. In this regard, Dassault was clearly ahead of CADAM, Inc. in the development of advanced software.

In late 1991, Puhl and six other CADAM, Inc. executives filed suit against Lockheed claiming that they were not compensated as expected when Lockheed sold the company to IBM. They believed they should have been paid bonuses based upon the total amount IBM paid for the company, not just the cash portion.

IBM had been subtly favoring CATIA for several years and it was not clear that owning CADAM outright would change this stance since the bottom line was that IBM wanted to sell as much hardware as possible. As Steve Wolfe commented in *Computer Aided Design Report*:

> "The favoring of CATIA did not go unnoticed by CADAM's managers and they were resentful. CADAM had been IBM's faithful wife, and even if she was not as attractive as she once was, that was no excuse for IBM to go running off with a new French mistress. Relations grew strained and CADAM began developing its own sales and marketing arm to seek distribution outside of IBM's main sales channels."

By the time of IBM's acquisition CADAM, Inc. had 16 sales offices and its own dealer network to distribute MICRO CADAM. This sales organizations was expected to be disbanded and sales responsibilities taken over by IBM.[48]

Contrary to earlier plans, Lockheed did not sell CalComp at this time and instead continued to operate it as a wholly owned subsidiary.

**Dassault Systèmes takes over CADAM**

In November 1991, IBM sold Dassault the mainframe and workstation versions of CADAM in return for a minority interest in Dassault Systèmes estimated at somewhat over ten percent. Approximately 200 of CADAM, Inc's 500 employees subsequently transferred to Dassault. CADAM Inc. retained development responsibility for MICRO CADAM, IBM CAD and P-CAD although IBM's interest in the P-CAD electronic design software waned fairly quickly. This deal had been brewing for nearly a year, initially with the intent that IBM would acquire CATIA from Dassault. Eventually, it ended up the other way around.

It was not entirely clear at the time how Dassault would blend the two product lines together. Although CADAM was still the better drafting solution, few customers were acquiring new licenses strictly for that purpose. CATIA's drafting, which at one time was virtually non-existent, was gradually improving.

On the flip side, while CADAM's three-dimensional modeling was slowly improving, it was no match for CATIA. As a result, most new licenses were CATIA. The expectation was that Dassault would take the good stuff from CADAM and eventually add it to CATIA but that this could take some time.[49]

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[48] *Computer Aided Design Report*, December 1989, Pg. 10
[49] *Computer Aided Design Report*, December 1991, Pg. 9

 

## CADAM, Inc. becomes ALTIUM

In the spring of 1993, CADAM, Inc. took on a new identity. It would henceforth be called ALTIUM. Not much else happened at that point in time. ALTIUM was headed by Lee Murray and had about 425 employees with revenues of about $150 million.[50] At the time, IBM was going through a major restructuring of its own and *Engineering Automation Report* thought that ALTIUM might actually be a model for the future of IBM. The common perception at the time was that IBM would become a collaboration of semi-autonomous business units each focused on a specific product or market area.

Altium operated as an independent company with its own salary and benefit plan. Its employees were considered ALTIUM employees – not IBM employees. When IBM acquired CADAM, Inc. from Lockheed only Murray and one other employee were transferred in from IBM. Perhaps IBM learned a lesson from the way General Electric mismanaged Calma when it acquired that company and replaced nearly its entire top management with GE employees who knew little about CAD/CAM. In addition, IBM did not load Altium down with corporate overhead charges. According to Murray, they were running it “as a typical California software company.”[51]

By the time ALTIUM was established, there were perhaps 75,000 copies of MICRO CADAM in use, many of them in Japan where it was a very popular software package. It was basically a 2 ½ -dimensional drafting package that used a technique the company called “Auxiliary Views” in order to provide three-dimensional capabilities. The primary competition in the PC mechanical drafting market were Autodesk’s AutoCAD and packages from Computervision and CADKEY. In relation to AutoCAD specifically, MICRO CADAM had strong data management capabilities, dimensioning, support of drafting standards, symbol libraries and its user interface. However, its price at $3995 was twice that of AutoCAD and ALTIUM had yet to develop the third party software support and channel distribution capabilities Autodesk had.

When *Engineering Automation Report* interviewed ALTIUM in the summer of 1993, the company was planning a new release of MICRO CADAM that would incorporate solids and surface geometry modeling as well as three-dimensional AutoCAD DWG and IGES translators. The company was known to be looking at two solid modeling kernels, ACIS from Spatial Technology and Designbase from Japan’s RICOH.

ALTIUM also continued to market IBM CAD which was now being maintained by a group of former IBM programmers who had set up their own company, JMI. Only 15,000 copies of IBM CAD had been sold and over 20 percent of these were used internally by IBM and another 30 to 40 percent were being used by educational institutions. In retrospect, there did not seem to be a good business case to keep this package in the product line and it was eventually dropped.

The third portion of the company’s product line was the P-CAD electrical design software that was primarily sold for use on PCs but was also available for UNIX workstations. ALTIUM never was able to create significant momentum in the electronics design market and dropped this product also.

This semi-independent operation had a relatively brief honeymoon. In October, 1993 it was announced that Alitum was dropping the development of a solids-based

[50] *Engineering Automation Report*, April 1993, Pg. 12
[51] *Engineering Automation Report*, July 1993, Pg. 6

 

version of MICRO CADAM, was reducing its staff by 24 percent and that future development of the MICRO CADAM software would be handled by CADAM Systems Company in Japan. It was also noted that future solids development by CSC would utilize the Ricoh Designbase modeler rather than Spatial's ACIS. At the same Altium was given the task of marketing electronic design software developed internally at IBM. These products included ProFrame and Logic-Bench which had been used by IBM Microelectronics to design the POWER line of processors.

In early 1994, the ALTIUM situation changed again, this time rather significantly. IBM's management assigned 16 different hardware and software products to ALTIUM ranging from data collection terminals to the architectural design software (AES) that IBM had developed years earlier with Skidmore Owens & Merrill. The company still had marketing responsibility for MICRO CADAM, IBM CAD and P-CAD. As part of this reorganization, ALTIUM headquarters were relocated from Burbank, California to Charlotte, North Carolina.

### MICRO CADAM Inc. enters the picture

As part of the 1994 restructuring of ALTIUM, IBM sold the development and marketing rights to MICRO CADAM to CSC although IBM continued to handle the marketing and sales of the package outside of Japan. By 1995, IBM's sales organization was showing little interest in selling additional copies of MICRO CADAM and CSC was faced with the need of building its own worldwide distribution organization, especially in North America and Europe.

One result of the MICRO CADAM sale was that about 35 former U.S.-based employees of ALTIUM became employees of a new CSC-owned company called MICROCADAM, Inc. This group relocated from the former ALTIUM facility in Burbank to new offices in downtown Los Angeles. Hiroshi Hara, the president of CSC since its founding in 1984 was also president of the new MICROCADAM subsidiary.

Dr. Jack Horgan, who had been with Applicon and was a co-founder of Aries Technology, soon became senior vice-president of MICROCADAM, Inc and basically ran the Los Angeles operation. Another key individual was Lee Whitney who was vice-president of product planning. As mentioned earlier, Whitney had been involved with CADAM since its start in 1965.

What started out as two similar versions of the same software had, by 1994, diverged significantly. Japan was starting to ship MICRO CADAM V3 while ALTIUM was launching MICRO CADAM Release 14. One example of the differences was that V3 was available in an OS/2 version while Release 14 was not. By late 1995 there were about 75,000 copies of MICRO CADAM in use including 40,000 copies in Japan. The primary product was MICRO CADAM PLUS although it was often referred to simply as MICRO CADAM. It was available in DOS, Windows and UNIX versions ranging in price from $3,995 to $4,795.

Version 14 had a much improved user interface with pull-down menus and pop-up dialog boxes. Up to five independent viewports, each with its own coordinate system, were supported. A change in one viewport was immediately reflected in the other viewports. There was also bi-directional DXF translation as well as direct translation between MICRO CADAM and AutoCAD. A user development capability called Access had been added as well as a low-cost viewing program.

 

Figure 13.7
MICRO CADAM Running on IBM PC

The most significant development in the 1995 time frame was the introduction of a solid modeling package called MICRO CADAM●Helix which used the Ricoh Designbase kernel. It was a fairly decent package with parametric design support, variational geometry implemented using D-Cube's constraint management software, assembly modeling, visualization and the ability to export data to MICRO CADAM for drafting. It was initially implemented on IBM and Hewlett-Packard UNIX workstations and sold for $3,495 or $7,895 with MICRO CADAM.

*Engineering Automation Report* summed up the situation at MICROCADAM in its September 1995 issue as follows:

> "We believe that MICROCADAM, Inc. has a tough, but not insurmountable, task ahead of itself in re-establishing marketplace momentum. Its products currently appeal to users who are heavily focused on production drafting. This market will diminish over time as interest in parametric modeling and variational geometry grows…….. In order to be successful, the company needs to focus on three critical issues: 1) expanding its product line so that it can offer users a broader solution suite, 2) increasing the number of third-party software developers interested in MICRO CADAM applications, and 3) building an effective North American and European distribution organization." [52]

Unfortunately, CSC and MICROCADAM were never able to pull this off. Although CSC continued to sell a substantial amount of drafting software in Japan where parametric

[52] *Engineering Automation Report*, September 1995, Pg. 6

modeling application had yet to take off, the U.S. market was slow to accept MICROCADAM as a viable vendor. Overall, CSC, including MICROCADAM, was doing about $160 million in annual revenues in 1997.

MICRO CADAM had long been sold as a low-cost alternative to mainframe CADAM. By 1997, most of those users had already switched to a PC or workstation substitute for design and drafting applications and this market for MICRO CADAM was drying up. As a consequence, the company changed its product and marketing strategy somewhat. MICRO CADAM as a separate product went away and was replaced by Helix Parametric Drafting. Priced at $5,695, it was available on both Windows systems and IBM RS/6000 UNIX workstations. A second product combined the Parametric Drafting software with the previously described Helix Modeling package as Helix Engineering. It sold for $8,695 and was only available on Windows. These packages replaced the separate versions on MICRO CADAM that had previously been sold in Japan and the U.S.

In March 2000, IBM acquired the remaining share of CSC it did not already own from Kawasaki, and announced the end of CSC and MICROCADAM. CSC had been successful in Asia but IBM felt that they could make better use of the CSC assets in support of CATIA. There was no need to keep any support outside Japan. IBM did continue to provide CSC products to existing customers for a period of time.

**IBM's Product Data Management activity**

Until the late 1980s, managing large volumes of engineering design data had not been a focused issue for either software vendors or users. For the most part, model and drawing files were managed simply using the computer's basic file management system. IBM offered a program called "Data Communication Service" or DCS that never really caught on with CADAM and CATIA users. In November 1989 a newer product, "CIM Communications and Data Facility" or CIM CDF was introduced. Like DCS, the new software used IBM's DB2 relational database management system on mainframe computers running the MVS operating system and SDQ/DS on VM systems.

Since CAD data was not organized in a format conducive to storing in a relational database form, IBM created a data structure it called a "long object." This enabled CIM CDF to store data about the data file such as which application created it, drawing title, version number, etc in the relational database and rapidly retrieve drawings and models based upon this information.

An additional layer of software was implemented by IBM to facilitate the use of CIM CDF. Called "IBM Product Manager: Engineering Management Edition" this software provided capabilities such as product structure management, product change management, routing data to manufacturing systems and cost evaluation. It was the start of a comprehensive Product Data Management or PDM solution. CIM CDF was fairly expensive software. On a large mainframe, the upfront software cost could exceed $400,000 along with subsequent support costs in excess of $60,000 per year. Initially, there were also concerns about the responsiveness of this complex software.[53]

**IBM business goes through a major transformation**

[53] *Computer Aided Design Report*, December 1989, Pg. 4

 

Many books and articles have been written about IBM's problems in the late 1980s and early 1990s and how Louis Gerstner was brought in from R.J. Reynolds to turn the company around – a task he did brilliantly. I will not attempt to duplicate that story here but will just cover enough to put this critical transformation into perspective for the rest of our story.

In the first quarter of 1991, IBM's product sales slid 11 percent followed by a devastating 17 percent drop in the second quarter. The media saw this as possibly the beginning of the end for a company that had once so totally dominated the computer industry. Overall, 1991 was the first year in the company's then 81-year history to show a sales decline. Total revenue was down 4 percent to $64.8 billion and the company incurred a $2.8 billion loss.

The major problem was that IBM was still wedded to the mainframe at a time when UNIX-based client/server systems were providing more throughput for the dollar and the PC was starting to become a viable business and engineering platform. The mainframe was far more profitable for the company than these alternative platforms would prove to be. IBM was slow to react to these changes, perhaps because its employees had simply become too comfortable with the status quo. IBM maintained a "no layoff" policy through the early 1990s and was only able to reduce its staff through early retirement, attrition and other incentives to quit.[54] The no layoff policy went into the trash can after the poor 1991 results and IBM announced a $3 billion special charge based on plans to layoff 20,000 employees.

Over the years, IBM had become too inwardly focused. Managers saw other IBM divisions as the competition rather than external firms. Far too much effort was spent in positioning each organization for these internal battles over who should be responsible for what. Internal management presentations were critical to ones success and promotion and producing quality slide shows became an art form. When Gerstner became CEO in 1993, one of the first actions he took was to inform those reporting to him that he wanted them to discuss issues without the help of slides and projectors. It was the start of a healthy rebirth of creative activity within the company.

For a period of time after Gerstner came on board, the Advanced Workstation and Systems unit seemed to function much like the other players in the technical workstation market. Likewise, this was the period of time when the company picked up considerable momentum in marketing CATIA and related software products. To keep the nomenclature straight, as of early 1994 the CADAM and CATIA marketing along with related software products was being handled by IBM Applications Solutions Division's Manufacturing Technology Center in Boca Raton, Florida.

### A chink in the IBM/Dassault relationship?

For a time in mid-1992 it appeared that IBM and Dassault Systèmes might be going their separate ways. Dassault set up a sales organization in the United States called Dassault Systèmes Services and announced that it would become a reseller of IBM RS/6000 workstations, apparently with Dassault software. The word in the industry was that Dassault was actively recruiting sales professionals to staff this new organization.

This was not a totally new activity on the part of Dassault. A sales and support organization, Dassault Systèmes U.S.A had actually been established as early as July

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[54] *Computer Aided Design Report*, September 1991, Pg. 1

 

1984. If there were major disagreements between the two parties, they managed to keep them mostly private and IBM continued to be the primary sales channel for CATIA as well as handling any residual CADAM activity.

**Dassault initiates a major upgrade of CATIA**

At the fall 1992 CATIA user conferences - the European CATIA User Association (ECUA) and the CATIA Operators Exchange (COE - as well as at AUTOFACT '92, Dassault announced a major CATIA upgrade planned for introduction in the second half of 1993. This was the first major overhaul of the software since 1988. Known as CATIA Version 4 it was planned to contain 1,567 functional enhancements including the following features:

- A precise solids modeler to replace the existing faceted modeler used in CATIA.
- The ability to mix surface and solid models.
- Dimension-driven parametric design including feature-based modeling.
- Real-time shading when the software was run on IBM RS/6000 workstations that incorporated GTO graphics cards.
- Assembly modeling.
- A MOTIF-like user interface.
- Associativity between the base model and drafting and NC applications.

Overall, this was an ambitious upgrade to what was a fairly complex product to start with. In order to compete with PTC and other modern design solutions, it was necessary to make these changes as soon as possible.[55] Version 4 was launched in October 1993 just before AUTOFACT'93. It was offered on both mainframes and RS/6000 workstations with the comment that other platforms would be supported starting in 1995. Shipment of both the RS/6000 and mainframe versions began in February 1994.

**Dassault shifts into high gear**

With the release of CATIA Version 4, Dassault Systèmes and IBM seemed to shift into a higher gear in regards to their sales and marketing momentum. By mid-1994 the installed base of both CADAM and CATIA was impressive as shown in the accompanying table:

| | CADAM | CATIA |
|---|---|---|
| Customers | 3,000 | 3,500 |
| Host Systems | 2,200 | 1,200 |
| Host-Based Seats | 55,000 | 27,000 |
| Workstation Seats | 5,000 | 13,000 |
| Total Seats | 60,000 | 40,000 |

Approximately 40 percent of the CATIA seats were in the automotive industry and 30 percent in aircraft and aerospace. CADAM was more prevalent at aircraft and aerospace companies and was not used as extensively by automobile manufacturers and their suppliers. According to Dassault, about half these seats were installed at customers who

[55] *Computer Aided Design Report*, November 1992, Pg. 5

 

used both CADAM and CATIA. Major CATIA accounts were Boeing, Chrysler and BMW.[56]

Organizationally, the former CADAM, Inc. operation in Burbank was now called Dassault Systèms of America (DSA). It functioned as a wholly owned subsidiary of Dassault Systèms and was headed by president Richard Merrill. One of the tasks facing the company at this time was convincing CADAM users that there was a future for that product and that they should stick with Dassault products rather than switching to competitive systems such as Pro/ENGINEER or I-DEAS. One way they did this was by referring to a number of software products as "CATIA/CADAM." Although maintenance work continued on CADAM it was fairly clear to nearly everyone that eventually that it would be phased out and replaced entirely by CATIA.

Although only IBM RS/6000 workstations in addition to mainframes were supported by CATIA V4 at this time, it was clear to nearly everyone that workstations from multiple vendors and PCs were the wave of the future and that the mainframes' time had come and passed in regards to interactive technical software. IBM was starting to realize that it had to be prepared to sell design and data management software on platforms the company did not manufacture if it were to continue being a major player in this industry. Plans were underway to start selling Professional CADAM on Hewlett-Packard Series 700 workstations towards the end of 1994 and CATIA on non-IBM workstations in 1995.

The February release of Version 4 was quickly followed up with Version 4 Release 1.2 (V4R1.2) which added feature based modeling to CATIA. The package now came with about 100 predefined geometric features such as pads, bosses, shafts, pockets, filets, and grooves. To these, users could add their own features that were stored in a feature library. When a feature was inserted into a part, its location and orientation were easily established and key dimension could be entered to determine the size and shape of the feature. An additional V4R1.2 capability was bi-directional associativity between CATIA drawings and the model these drawings were derived from. A change to the model would change the drawing while a dimension change in a drawing would update the model.

The CATIA product line consisted of 54 distinct software packages. Typically, they were combined in 20 different task related bundles targeting specific application requirements. Prices ranged from $6,000 for Mechanical Drawing Production, to $20,500 for Mechanical Advanced Part Design and $40,000 for Mechanical Advanced Assembly Design. IBM sold bundled systems as well as per seat software licenses. An RS/6000 Model 365 workstation with the Advanced Part Design software cost $50,794.

In the 1994 time frame, the CADAM and CATIA installed base was under ferocious attack from two directions. Autodesk was pushing AutoCAD as a low cost alternative to CADAM with a fair amount of success while PTC, SDRC and UGS were pushing their conceptual design solutions as an alternative to both CADAM and CATIA on the basis that the Dassault products were obsolete technology. With the launch of V4 and particularly with V4R1.2, CATIA was generally competitive with these newer designs solutions. On the other hand, Dassault did not yet have a good answer to AutoCAD in regards to the low-cost PC market. MICRO CADAM was the responsibility

[56] *Engineering Automation Report*, August 1994, Pg. 6

of a different company and had basically disappeared from the user community's radar screen, especially in North America.

Also with the release of V4, the relationship between IBM and Dassault seemed to solidify and the talk about Dassault setting up a separate sales channel for CATIA simply melted away.

**CATIA-CADAM and plant design**

Although most of Dassault's and IBM's focus was on the mechanical market, CADAM and CATIA were also used for AEC applications, primarily process plant design and shipbuilding. Some companies, particularly General Motors, also used CADAM for facility design work such as the layout of manufacturing plants. CADAM, Inc. began developing piping design and drafting software in 1978, working with Avondale Shipyards.

The initial CADAM product used a combination of three-dimensional techniques for piping tasks and two-dimensional representation of non-pipe plant elements such as tanks and pumps. The software was intended to reduce the manual effort required to produce dimensioned spool diagrams (sections of pipe that would be fabricated as an assembly).[57] The Avondale software, referred to as Phase I and based on CADAM Release 18.3, was delivered to customers in October 1978.

Subsequently, CADAM Inc. signed a joint development agreement with Chiyoda Chemical of Japan in December 1982. The result of this endeavor, Phase II or CADAM 3D Piping, was first shown at the Systems '83 show in June 1983 in Dallas. My impression at the time was that it was very fast compared to other piping design systems I had seen. IBM also began pushing CADAM at about the same time for architectural and facility design.

The following year, IBM demonstrated CADAM DBM (Design, Build and Manage), an application layer that sat on top of CADAM and contained software for drafting wall layouts, generating component schedules and a library of standard details. The wall software worked in single line mode and then converted the layout to a traditional double line version in a batch process. IBM also demonstrated using CATIA to create building models. This was 1984 and the interactive performance was just not there. It would be another decade before we would see significant architectural work done with CATIA by architects such as Frank Gehry.

By 1985, there was confusion over whether CADAM or CATIA would be IBM's preferred AEC product. At Systems '85 the company had demonstrations using both packages. One problem with using CADAM for architectural design was that it could not generate shaded images on the 5080 display. Data had to be transferred to CATIA to do that.

*A-E-C Automation Newsletter* had an extensive review of CADAM's Plant Design System in its January 1987 issue. At the time, there was supposedly 150 installations of CADAM's plant design software which consisted of ten different modules. The piping design aspects of this software were fairly impressive. The software came with a basic library of 4,500 piping components along with the ability to create custom libraries.

[57] *Computer Aided Design Report*, April 1984, Pg. 8

 

Piping layouts could be displayed in a variety of single line and double line modes. Users could route piping components in multiple different ways and display the results in both orthographic and isometric modes. There was one major problems with using CADAM for plant design – that was the software's 64 KB file size limit. As a result, large plant designs were done as a series of overlay models, perhaps as many as 200 of which 20 could be viewed simultaneously.[58]

Eventually there were two versions of the plant design software, one built around CADAM, the other based on CATIA. After Dassault took over CADAM from IBM the plan was to bring these two versions together to support what the company called the "Virtual Plant." Much of this development work was untaken at the DSA facility in California.

The new software was database intensive with object oriented features. It had parametric design capabilities, rule-based model checking and open platform support. Initially it was called CATIA/CADAM AEC Plant Solutions and supported detailed piping design, interference checking, and space management. This was the start of the move towards supporting process plant and shipbuilding design with software utilizing solids modeling at its core. It required the software architecture to mature to the point where these tasks could be done swiftly and accurately and the processing power of moderately priced workstations to progress to the point where they could handle large-scale modeling tasks effectively.[59]

The obvious question is why wasn't IBM more successful selling AEC software, especially to plant engineering and construction organizations. My personal opinion, supported by other industry observers, was that IBM simply never had industry knowledgeable sales personnel in sufficient numbers focused on this market.

**IBM and Skidmore, Owings and Merrill attack the architecture market**

Skidmore, Owings and Merrill (SOM), the large Chicago-based engineering and architectural firm, was an early adopter of computer technology. The company began developing structural engineering software in 1962 using an IBM 1620. In 1967, G. Neil Harper[60] and David Sides implemented a building planning program on an IBM 1130 computer. Building Optimization Program (BOP) used a linear programming technique to determine the optimum number of floors, number of elevators, structural bay size, etc. for a given size site and required floor space. SOM also developed other applications for hospital space planning and the storage and analysis of client requirement information.

In the early 1970s, Douglas Stoker became involved in SOM computer activity, initially developing software that was used to prepare input data for the structural analysis of buildings such as the Sears Tower in Chicago. This work was also done on the IBM 1130. By the mid-1970s, Stoker, along with Bill Kovacs[61], Nick Weingarten and others at SOM, began developing a comprehensive suite of architectural design and engineering programs.

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[58] *A-E-C Automation Newsletter*, January 1987, Pg. 3
[59] *Engineering Automation Report*, August 1994, Pg. 6
[60] Neil Harper was a classmate of mine at MIT. After SOM he went on to start Harper and Shuman, a vendor of construction management software.
[61] Bill Kovacs went on to start Wavefront Technology, a graphical visualization software company in Santa Barbara, California which was subsequently acquired by Silicon Graphics and merged with another SGI acquisition, Alias Research to form Alias|Wavefront.

Initially this work was done on a Digital PDP 11/45 and a PDP 11/70 using Tektronix graphics terminals. Eventually, the PDP 11s were replaced by a VAX 11/780. The software was used to create three-dimensional wireframe models of buildings as well as produce construction drawings. The early version of the software was simply called DRAFT.[62] Stoker and others at SOM were convinced that the traditional CAD companies could never understand the intricacies of building design as well as a design firm could. Except for some analysis software, SOM primarily used software it developed internally for many years.

By 1986, SOM sensed that minicomputers such as Digital's VAX systems were falling behind technically and the firm began switching to the new IBM RT-PC described earlier. It is not clear exactly when SOM began discussion with IBM to have the latter company market SOM's architectural and engineering software. In November 1986 the two companies signed an agreement that called for SOM to convert and extend the DRAFT software to run on the RT-PC using the IBM 5081 display. The overall project, which had nearly 50 people assigned to it, was called the SOM-SKYLINE Project. The first DRAFT module planned for delivery to IBM customers was to be called Base Graphics System.

Figure 13.8
Bill Kovacs and Doug Stoker in SOM Computer Room Around 1977[63]

Ed Forrest, writing in the May 1987 issue of *A-E-C Automation Newsletter* was extremely excited by this new collaboration between SOM and IBM. "Having been shown the master plan of the software products proposed to IBM by SOM, I assure you I know of no existing product(s) anywhere near it nor am I aware of any being proposed."

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[62] Fallon, Kristine, *The AEC Technology Survival Guide*, Pg. 151
[63] Fallon, Kristine, *The AEC Technology Survival Guide*, Pg. 153

 

Stoker was equally enthusiastic in the same issue of the newsletter about the potential for this new software to be used to manage the entire lifecycle of a building. “That’s where we’re heading with SOM-SKYLINE. We’re heading to create a design tool that can be used as a geometric access method to information describing the built-environment.[64]

The SOM software was renamed AES (Architecture Engineering Series) and was sold by IBM for a number of years. When SOM dropped support of AES, it was picked up by Premisys Corporation where Weingarten was involved in maintaining the software. SOM itself, has moved on from using AES to Autodesk’s AutoCAD and Revit.

**Dassault adds multi-platform support**

Dassault Systèms continued to roll out new releases of CATIA at a fairly regular clip. CATIA Version 4 Release 1.4 was announced in March 1995. This release contained improved geometric modeling capabilities, improve data handling between applications and improved CADAM/CATIA interoperability. The most significant step, however, was the announcement that the software would be supported on both Hewlett-Packard and Silicon Graphics workstations. Obviously, IBM sales personnel were not going to promote these versions over the RS/6000 implementation but if the customer was an HP or SGI shop they still wanted to sell them the software. CATIA became available first on SGI workstations in March 1996. In the first two years, nearly 10,000 copies of CATIA were sold on the SGI platform.[65]

Dassault continued to roll out new releases about every six months. V4R1.5 came out in October 1995 with new modeling capabilities and increased the number of distinct modules to 78. The most significant development was the introduction of the CATIA/CADAM AEC Plant Solutions package described earlier. It was built around CADAM’s two-dimensional drafting and CATIA’s three-dimensional modeling capabilities. There was also a new CATIA Shipbuilding module that could be used to design ship hulls and superstructure while Plant Solutions was used to design the interior of ships.

By the spring of 1996, V4R1.6 was being shipped to customers and the term CATIA/CADAM Solutions was being used with more frequency. This software had improved dynamic sketching capabilities, a two-dimensional freehand tool that automatically constrained geometry called Sketchit! and the integration of Imageware software for free form surface design. At this point, many CADAM users had migrated to competitive systems and IBM and Dassault wanted to project an image that there was still a future for these users by installing software that blended together the best of CADAM and CATIA. Also, the first Windows NT implementation was available, CATIA/CADAM Drafting.[66]

An example of the two companies determination to make the multi-platform concept work was at the spring 1996 CATIA Operators Exchange meeting in Miami Beach where the presentation on the future of computer technology was given by Hewlett-Packard’s Dick Lampman. IBM management emphasized that its CAD sales

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[64] *A-E-C Automation Newsletter*, May 1987, Pg. 8
[65] *Engineering Automation Report*, July 1998, Pg. 10
[66] *Engineering Automation Report*, April 1996, Pg. 12

 

personnel were platform independent and received the same commission irrespective of the platform the software ran on.[67]

As mentioned earlier, marketing and support of CATIA was handled by IBM's 800-person Engineering Technology Solutions (ETS) group which was part of the larger Manufacturing Industries Solutions business unit. Dr. Frank Lerchenmuller, the IBM vice-president in charge of ETS, was located in Paris just a few minutes from Dassault Systèmes. IBM was focused on selling to large accounts and was developing a distribution channel to handle smaller accounts. *Engineering Automation Report* felt positive about Dassault and IBM's future in the CAD industry:

> "…*EAReport* believes that the coming five years will see significant consolidation in the industry. Our expectation is that the IBM/Dassault partnership will be one of the survivors and will probably be in one of the top two or three positions."

This definitely is what eventually happened. By mid-1996 Dassault Systèmes was planning an initial public offering.[68]

One of the more difficult tasks facing CATIA users was that it could take up to several days to load CATIA on an RS/6000 workstation using software from multiple sources. In April 1997 IBM began shipping a new CD called "The RS/6000 Operating Environment for CATIA" that included all the software needed to run CATIA. It reduced the time needed to load a typical implementation to just a few hours.

By the time V4R1.8 came out in mid-1997, the entire CATIA-CADAM product suite consisted of 108 distinct programs. One reason behind this large number of modules was that Dassault tended to split functionality into more separate programs than did most other vendors.

The relationship between Dassault's data management capabilities and those of IBM was starting to coalesce about this time. The CATIA Data Management (CDM) program provided graphical product structure management while IBM's ProductManager handled configuration management and change control. Slowly but surely, IBM's PDM software was taking on more Internet characteristics. A Java-based Web browser was added to the ProductManager client software.

CATIA V4R2.0 came out in the late summer of 1998. A major effort was put into enhancing the software capabilities to support the digital mockup of complex assemblies and visualizing the resulting models. CATIA 4D Navigator was the primary module for supporting this task. By now there were 115 CATIA modules in the entire V4 product suite.

**Dassault goes public and acquires SolidWorks**

In 1995, Bernard Charlès became president of the Dassault Systèmes. He had been in charge of the company's R&D efforts as well planning its long term strategy. In 1996 the company went public with its shares listed on both the Paris bourse and NASDAQ.

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[67] *Engineering Automation Report*, May 1996, Pg. 12
[68] *Engineering Automation Report*, July 1996, Pg. 12

On June 24, 1997 Dassault Systèmes and SolidWorks Corporation announced that Dassault would be acquiring SolidWorks for $310 million. At the time SolidWorks had sold about 6,000 copies of its SolidWorks software to about 3,000 accounts and was generating approximately $25 million in annual revenue. This meant Dassault was paying over 12 times annual revenue for a fairly new company. Rich but not unheard of in the heady days of the period as the dot com boom was starting to explode.

The July issue of *Engineering Automation Report* commented;

> "Miller (Dick Miller, then vice-president of ANSYS) and others seem to think that this acquisition will put pressure on Parametric Technology in that it will squeeze that company between a well positioned high-end vendor and the fastest growing mid-range software provider in the CAD industry. Our observation is somewhat different in that we believe it will have a greater impact on other mid-range mechanical CAD Vendors such as Intergraph (then vendor of Solid Edge), Autodesk, Bentley and Cad.Lab. Time will tell."

In retrospect, both Miller and *EAReport* were probably correct.[69]

As noted elsewhere, since Dassault operated SolidWorks very much as an independent subsidiary, it will be cover in a separate chapter. (See Chapter 18.)

**Establishing a presence in manufacturing automation**

Until late 1997, Dassault focused primarily on automating design and drafting tasks with a moderate amount of strength in the NC area. This began to change in December 1997 when the company announced plans to acquire Deneb, an Auburn Hills, Michigan vendor of robotics programming software, for $105 million in cash. Estimates were that Deneb had $18 to $20 million in annual revenues at the time of the acquisition meaning that Dassault was paying five to six times revenue, substantially less than the 12 times revenue it paid for SolidWorks.

The company made several subsequent acquisitions in this area including the Delta subsidiary of Engineering Animation which developed process planning software and Safework, a vendor of ergonometric software. In June 2000, this group of companies were put together as a single business unit named DELMIA. For the most part, the software products developed by this group continued to be distributed by a separate distribution channel, independent of IBM.

**Dassault gets serious about PDM**

In early 1998 it was obvious to industry observers that there was a serious disconnect in Dassault Systèmes' product and marketing strategy. While CATIA-CADAM was becoming a strong enterprise level design solution, between IBM and Dassault they offered fairly mediocre Product Data Management software, especially when compared to products such as SDRC's Metaphase. A major step towards resolving this shortcoming occurred in February 1998 when Dassault announced that it was establishing a new PDM business unit in Charlotte, NC called ENOVIA. It was to be managed by Joel Lemke who previously had been general manager of IBM's Global

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[69] *Engineering Automation Report*, July 1997, Pg. 1

 

Manufacturing Industries Unit. Putting someone with Lemke's experience in charge of this new group sent the message that Dassault was serious about the PDM market.

The reason that this new group was set up in Charlotte was because the primary software it would be working with was IBM's ProductManager which Dassault acquired from IBM for $45 million. IBM's commitment to the PDM market consisted of establishing two new worldwide organizations. IBM PDM II Solutions marketed and sold ENOVIA products independently of the group that sold CATIA and IBM Enterprise Engineering Services provided consulting and implementation services in the PDM area. This latter activity was in recognition that much of the money to be made in regards to PDM software was in helping users understand the technology and the steps necessary in successfully implementing it. The plan was clearly to sell PDM software to users of design software other than CATIA. Subsequently those two business units were renamed IBM PLM[70] Solutions and IBM Global Services (IGS), respectively.

ENOVIA was actually Dassault's second acquisition in the PDM space. In early 1999, the company had acquired a 75 percent interest in Smart Solutions, Ltd., a vendor of moderately priced department-level PDM solutions based in Tel Aviv, Israel. Initially it was closely linked with SolidWorks but eventually came to be seen as an alternative to ENOVIA, especially for use with CATIA V5. Smart Solutions is now known as SMARTEAM. IBM PLM Solutions handles the sales and marketing of SMARTEAM software used with CATIA and non-Dassault CAD systems while a separate SMARTEAM channel works with SolidWorks users.

## CATIA Version 5 breaks with the past

At the Design Engineering Show in March 1998, Dassault Systèmes previewed CATIA Version 5. The company had been working on this new software for some time under the code name "CNext." The software was being written specifically for Windows NT in C++ used object-oriented programming methodologies. It was developed from the start using newer standards such as STEP and OpenGL. Only a limited amount of functionality was ready to be demonstrated at NDES but the software was fast and the user interface was streamlined from what CATIA V4 used.

It appeared at this early date that V4 and V5 would have to co-exist for some period of time. *Engineering Automation Report* was cognizant of the potential problems the transition from V4 to V5 might cause. "We believe that IBM and Dassault need to plan the transition from 4 to 5 very carefully or the two companies stand the risk of duplicating the disaster Computervision went through several years ago when that company moved its customers from CADDS 4X to CADDS 5."[71] Without getting ahead of the story, they eventually did an admirable job managing the transition although nearly a decade later, many customers are still using V4.

In 1998, Dassault shipped V5 to an initial group of 25 customers with widespread distribution planned for 1999. It was obvious that moving model data between V4 and V5 was as difficult as moving it between software packages from two different vendors. V5 began shipping with both Windows NT and UNIX implementations in volume in March 1999, nearly a year after it was first announced.

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[70] PLM or Product Lifecycle Management was rapidly replacing PDM as the preferred term for data management activities related to product design, manufacturing and support.

[71] *Engineering Automation Report*, April 1998, Pg. 3

 

In August 1999, Dassault began shipping Release 2 (V5R2) which included a lower priced yet quite functional version called Platform 1 (P1). It was intended to attract

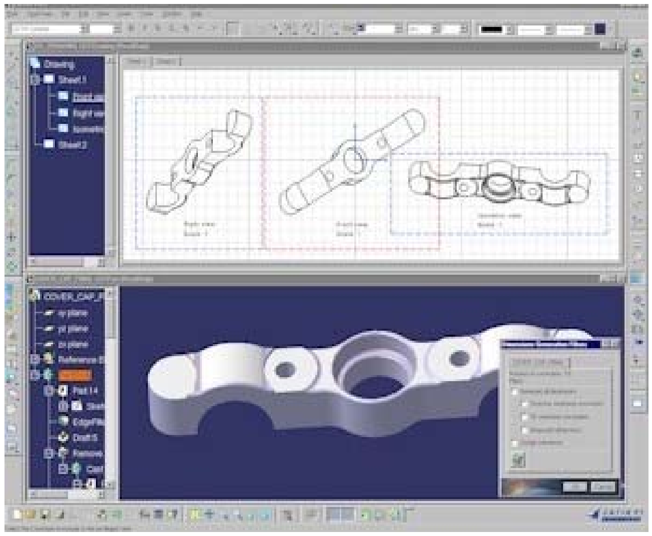

Figure 13.9
CATIA V5R2 Generative Drafting created multiple drawing views from a solid model

potential customers in the machinery, consumer goods and electronics markets. The full-function version of V5 was subsequently called Platform 2 (P2). V5R2 incorporated much of the two-dimensional drafting and three-dimensional surfacing capabilities that had not made it into the first release. P1 offered about 80% of the functionality of P2 and the two versions were bi-directionally compatible. While P2 ran on both UNIX and Windows NT, P1 also was available for use on Windows 95 and Windows 98. Pricing for P1 began at $4,500 for the two-dimensional solution and under $10,000 for the three-dimensional solution. P2 was priced at $7,500 and $13,000 respectively.

V5R3 was released in early 2000 with design rule checking and assembly mock-up. The Windows NT version was gaining increased acceptance, especially since it outperformed some of the UNIX implementations.[72]

**Dassault picks up remnants of Matra Datavision**

Matra Datavision, (discussed in Chapter 21) the developer of the EUCLID suite of design, analysis and manufacturing applications had been struggling for some time. The company had some very good surfacing software after it acquired Cisigraph and its STRIM soft several years earlier. Two companies were thought to be interested in acquiring Matra Datavision, Autodesk and SDRC. Autodesk turned out to not be interested and SDRC basically took itself out of the running when it acquired Imageware Corporation, another vendor of surface geometry software.

Few people were terribly surprised when Matra Datavision, Dassault Systemes and IBM announced a three-party agreement under which:

[72] *Engineering Automation Report*, January 2000, Pg. 11

 

- Dassault acquired a Matra Datavision subsidiary to which ownership of EUCLID STYLER, EUCLID MACHINIST, STRIM AND STRIMFLOW had been transferred. In addition, Dassault picked up a license to use Matra's CAS.CADE software development technology. Approximately 90 developers who had been working for Matra became Dassault employees.
- Dassault planned to integrate the acquired packages into CATIA V5. This was intended to provide users with enhanced free-form surface definition, machining and plastic part design capabilities.
- Matra Datavision announced that it would continue to support EUCLID 3 and CAS.CADE but not solicit new customers for that software
- Matra Datavision then became a reseller of Dassault software including CATIA, CATWEB, ENOVIA and Deneb's Digital Manufacturing software as an IBM International Business Partner.

The expectation was that that many of Matra's EUCLID customers would eventually move to CATIA, particularly the new Windows NT-oriented V5. Dassault did not pay a lot for the Matra software products, perhaps $40 to $50 million.

**Dassault acquires Spatial Technology**

In July 2000 Dassault Systèmes and Spatial Technology announced that Dassault would acquire Spatial's component software operation including the ACIS 3D Toolkit for $21.5 million in cash. Spatial had been putting an increasing amount of its efforts into developing Web-centric services for the design community and had decided that its future lay in this area rather than in the solids modeling kernel business. The money from Dassault was intended to finance Spatial's Web activity known as PlanetCAD. Subsequent to the acquisition, Dassault would own the Spatial name and the remainder of the company would be renamed PlanetCAD, Inc.

Several months later the offer was increased by $4.5 million to a total of $25 million. This was done in reaction to a counter offer for Spatial from SDRC for $26 million plus a guarantee of an additional $2 million in revenues for PlanetCAD services from SDRC customers. Dassault also agreed to a number of technology sharing agreements and joint marketing efforts with PlanetCAD. Spatial's board considered the revised Dassault offer to be "functionally equivalent" to that of SDRC.

According to a Spatial's filing with the SEC regarding the acquisition, "the board determined that given their relative size and market positions, the future support and relationship with Dassault and Dassault Systèmes would be more beneficial to PlanetCAD than the relationship proposed by SDRC."[73] The deal was completed in November.

Bruce Morgan, then CEO of Spatial, stayed with the PanetCAD portion of the business and Mike Payne who had been a founder of both PTC and SolidWorks took over running Spatial for the next several years. The issue that made this acquisition hard to understand was that Dassault's SolidWorks subsidiary was using UGS' Parasolid kernel and showed no interest in switching back to ACIS just because Dassault now owned it.

[73] *Engineering Automation Report*, October 2000, Pg. 12

Under Dassault, Spatial continued to enhance ACIS using existing and new Dassault technology and while not thriving, continues to have a fairly respectable component software business as this is being written.

**IBM and Dassault in the 21st century**

By mid-2000 the relative positioning of CATIA Version 4 and Version 5, at least in the near term, was starting to become clearer. V4 continued to be Dassault's flagship product in the automotive and aerospace industry as long those customers were willing to stick with UNIX-based solutions. V5 was targeted more at small to medium sized user organizations that were looking for a tightly integrated solution from a single vendor. Since V5 came in both UNIX and Windows flavors, it also served as the replacement package for UNIX-based V4 users who wanted to migrate to Windows. Dassault's SolidWorks was a traditional mid-range product that required third-party packages to provide a complete design, analysis and manufacturing solution. The latter product continued to be marketed separately from CATIA.

In July 2000 new versions of both V4 and V5 were announced. It was obvious the predominant amount of development effort was going into V5, but Dassault was still enhancing V4, not just doing cosmetic maintenance. V4R2.3 contained modeling, analysis and manufacturing enhancements. These paled, however, compared to the 12 new V5 modules the company introduced along with enhancements to 39 other V5 modules that covered everything from generative drafting to freestyle sketching and structural analysis. V5 was rapidly becoming an industrial strength suite of software products.

Dassault continued to make acquisitions to expand its product offerings. On March 30, 2001 it announced that it would acquire Structural Research and Analysis Corporation of Los Angeles for $22 million in stock. SRAC was the developer of the well-respected COSMOS family of structural analysis software products that were used extensively with mid-range CAD solutions. In particular, it was the analysis software used most frequently with SolidWorks. As described in Chapter 22, SRAC became a subsidiary of SolidWorks and the COSMOS software was tightly integrated with SolidWorks and in fairly short order the company began distributing the analysis software as COSMOSWorks.[74]

Dassault Systèmes of America was the Woodland Hills, CA remnant of the original CADAM organization. Under Phillippe Forestier, it was responsible for the development of CATIA-CADAM Plant, CATIA-CADAM Drafting and support of the legacy CADAM software that was still being used extensively. In what is probably a CAD industry longevity record, Rick Watanabe celebrated 40 continuous years involved with CADAM in 2007 - initially as a CADAM user and manager at Lockheed, as a manager at CADAM, Inc. and as CADAM support manager at Dassault Systèmes of America

The company was more frequently referring to the combination of CATIA, ENOVIA and DELMIA as its overall PLM or Product Lifecycle Management solution. At the Fall 2001 CATIA Operator Exchange meeting in Orlando, Florida the company

[74] *Engineering Automation Report*, May 2001, Pg. 6

 

made a pitch that henceforth it wanted to be referred to simply as DS rather than Dassault Systèmes and at the same time introduced a new corporate logo using the term "3DS"[75].

The major development in early 2002 was that Toyota Motor Corporation had selected CATIA V5 as its primary vehicle design system replacing its internally developed TOGO CAD. The latter software had been developed since 1993 by a subsidiary, Toyota Caelum, The procurement was a $150 million deal for 10,000 seats, not counting new hardware and support services to be provided by IBM. It should be noted that PTC retained much of its powertrain design business at Toyota.

An extensive article by Brad Holtz in the July 2002 issue of *Engineering Automation Report* explored the relationship between IBM and Dassault in some depth. A substantial portion of the article described how the two companies saw the PLM market evolving. Dassault used the term "3D PLM" to describe the design software that constituted this area. IBM took a broader view where it saw "PLM" as a solution for sharing product data across all aspects of a company. In IBM's eyes, PLM consisted of software, middleware, hardware and services.

IBM is clearly focused on selling enterprise-level solutions to large organizations. These solutions consist primarily of CATIA, Enovia and SMARTEAM software from Dassault complemented by other software products and services from IBM itself as well as other business partners. It does not seem to bother IBM that Dassault has other products such as SolidWorks, COSMOSWorks and ACIS that are sold through other channels. Hotz's summary of the relationship between the two companies was that "The relationship is stronger than ever" but that "Right now, IBM and Dassault Systemes need to coordinate their message"[76].

By 2006, Dassault Systèmes was a $1 billion company growing over 25 percent annually. In May of 2006 it completed the acquisition of MatrixOne for $410 million in cash. Now known as ENOVIA MatrixOne, it greatly enhanced the company's PLM offering. In mid-2007, Dassault acquired ICEM, Ltd., the vendor of ICEM SURF, for the equivalent of $69 million. (See Chapter 21)

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[75] *Engineering Automation Report*, November 2001, Pg. 10
[76] *Engineering Automation Report*, July 2002, Pg. 1

# Chapter 14

# Intergraph

## Introduction

Of the “big five” CAD vendors in 1980, Applicon, Auto-trol Technology, Calma, Computervision and M&S Computing, only the last of these, now known as Intergraph, is still a viable thriving business although it has also had its share of highs and lows.

The history of Intergraph from the mid-1980s on cannot be completely separated from the history of Bentley Systems, the company that developed and currently markets MicroStation. This chapter will describe the MicroStation story from Intergraph’s point of view, leaving it to a separate chapter on Bentley (Chapter 10) to describe in depth the breakup of this corporate partnership and how Bentley eventually went its own way.

## Establishment of M&S Computing

Intergraph was started as M&S Computing in February 1969 by a group of engineers who were working for IBM’s Federal Systems Division in Huntsville, Alabama developing guidance software for the Saturn rocket. The group consisted of Jim Meadlock, his wife Nancy, Terry Schansman (the S of M&S), Keith Schonrock, and Robert Thurber. James Taylor joined three months later as employee #6.

This was an extremely loyal group of founders with all of them except for Schansman sticking with the firm through the 1980s and much of the 1990s. In fact Taylor was the company’s president and CEO when he retired for the second time in July 2003. Schansman left the company when it went from being a software contractor to marketing turnkey graphics systems. He wanted to stay in the software business. Unfortunately, he died from a heart attack a few years later.

M&S Computing was founded on the assumption that government agencies would begin to use digital computers for real-time missile guidance rather than the analog computers used up until then and that as a private company there would be business opportunities exploiting this change in technology. Some of the company’s early work was with NASA and the US Army in developing systems that applied digital computing to real-time missile guidance issues. Like most start-ups, the company took on whatever work that would help pay the bills. Many of these assignments ended up using computer graphics to display data such as simulated missile trajectories.

An important early project was the development of an interactive graphics system for the design and layout of printed circuit boards. This NASA effort fundamentally launched the company into the computer graphics business. Later, the software was expanded to cover the design of integrated circuits. According to Meadlock, being able to perform computer graphics independent of a programmer was a novel concept at the time.[1] The initial minicomputer version of this software was implemented on Xerox (formerly Scientific Data Systems) Sigma 5 and Sigma 2 computers.[2]

[1] http://www.geoplace.com/gw/1999/1099/1099jim.asp
[2] *CAD/CAM Alert*, March 1982, Pg. 2

M&S Computing's name was changed to Intergraph (**Inter**active **graph**ics) in 1980 prior to the company initial public offering in 1981. For simplicity, the company will simply be referred to as Intergraph throughout the remainder of this chapter.

**Jim Meadlock dominates company**

No story about Intergraph can be complete without a detailed discussion about Jim Meadlock and his influence on the company for nearly 30 years. Meadlock received a degree in electrical engineering from North Carolina State University in 1956 and worked on the Apollo space program at IBM for 12 years before founding Intergraph. The work mostly involved the development of software used to guide, control and check out the Saturn Launch Vehicle. Meadlock's electrical engineering background was particularly influential on many business and product decision he would make while CEO of the company.

To describe Meadlock as a controlling individual would be an understatement. Other than an interest in being a gentleman vintner, his entire life as well as that of his wife Nancy revolved around the company even to the point of building a home virtually on the company's industrial campus just west of Huntsville. Between them, the Meadlocks controlled expenses as if each dollar came out of their own pockets. One programmer once told me that that he needed Nancy's personal approval to obtain a programming manual for a computer system he was working on. There were contradictions however. Meadlock frowned on employees flying first class even if they were doing so on a free upgrade. On the other hand, Intergraph was the only CAD company that had its own corporate jet.

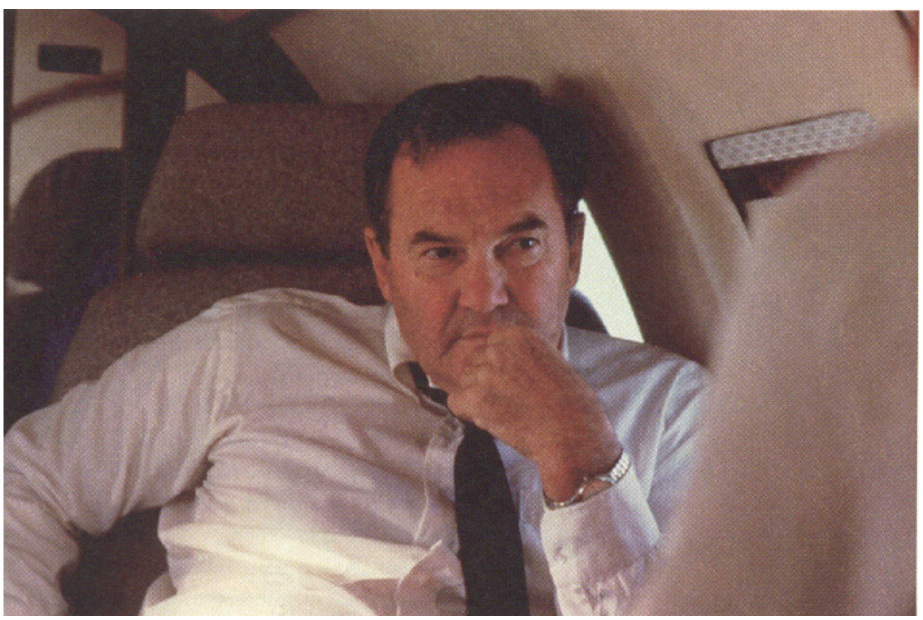

Figure 14.1
Jim Meadlock on Intergraph's Corporate Jet

Like many other engineering entrepreneurs Meadlock did not have much use for traditional sales and marketing. His attitude was if you built a good product the customers would come. In the late 1970s, the company had just a handful of sales people and promotional literature consisted mainly of black and white product data sheets. The primary sales technique was to bring the prospect to Huntsville where Meadlock would lay on his considerable charm.

As described below, Meadlock was brilliant product strategist. Each major product decision the company made seemed to lead to the next significant development. Throughout the latter part of the 1970s and the 1980s there was very little wasted motion within the company's product development activity. In particular, Meadlock had an excellent feel for the relationship between software and hardware, particularly at a time when the CAD industry was dominated by hardware-oriented turnkey systems. But he was stubborn and this stubbornness led to both difficulties and successes at Intergraph. The company probably stuck with manufacturing its own workstations and PCs far too long but when it switched platforms, it never looked back.

Probably the ultimate example of Meadlock's stubbornness, however, involved Intergraph's protracted legal dispute with Intel over microprocessor patents. At a time when most industry observers felt that Meadlock was tilting at windmills, he was determined to see the issue through, mainly because he absolutely believed his company was right. As described later in this chapter, he was proven to be correct, to the tune of many hundred million dollars.

Meadlock received numerous awards during his career including being one of 15 individuals to receive a 1985 Congressional High Technology Award. He was also given an Ed Forrest award for contributions to the CAD industry at the 1994 A/E/C SYSTEMS Conference in Washington, D.C.

**Intergraph enters the commercial graphics market**

In the early 1970s, Intergraph was still basically a consulting company. The market for turnkey graphics systems was taking off very slowly, mostly for the design of printed circuit boards and integrated circuits. There was one consistency in this technology and that was the concept of data layers. Designs consisted of two-dimensional representations of data elements and these layers were stacked one on top of another.

Meanwhile, nearby in Nashville, Tennessee a young Ph.D. mathematician, Dr. Joel Orr, had been hired by the city to direct the development and deployment of LAMP, metropolitan Nashville's Location And Mapping Program. The need for a municipal mapping system had its origin in a request from the Tennessee governor in 1972 for municipal support of a traffic accident reporting and analysis system. As the system manager responsible for establishing a geocoding methodology for the Nashville Metro Area (it was a combined city and county government), Orr looked at alternatives to handle widely varying requirements. While engineering needed precise data, the planning department could work with more generalized data.

A $300,000 budget was established in 1973 to procure a system for digitizing and managing geospatial data. Orr set out to see what other cities such as Houston, Atlanta and Eugene, Oregon were doing to establish digital map databases. Based on his findings a Request For Proposal was prepared and distributed to potential bidders. Nashville received 40 responses including proposals from Synercom and Calma which were both more established in this market than was Intergraph.

 

Although Intergraph did not have a mapping system per se, it proposed to convert the software the company had developed for integrated circuit design to manage geospatial data. (Nobody referred to it as "geospatial" at the time.) Intergraph agreed with Orr that digitized maps could be viewed on a CRT screen, edited interactively and a wide range of reports could be generated for municipal organizations such as school districts and fire and police departments.

According to Orr, one of the major reasons Intergraph won the contract for this system was that it was willing to interface the interactive mapping system to Nashville's IBM 370/145 mainframe computer. That computer had a huge amount of disk storage for the time, ten removable disk drives, each with the capacity of 300MB. Orr realized that the mapping system would generate a tremendous volume of data, far more than could be stored on the minicomputers then available.

The system proposed by Intergraph consisted of a Digital PDP-11 computer with a 24K 16-bit word memory and a 5MB disk drive, four Tektronix 4014 terminals, Summagraphics digitizers and an early version of what eventually became the company's primary graphics software package, IGDS (Interactive Graphics Design System). This particular version of the software was called IGDS3. The memory was soon increased to 48K words. One problem discovered soon after the system was installed was that it could only process straight lines and circular arcs. Since Nashville ran along side a river, irregular curves were needed. When this was pointed out to him, Keith Schonrock returned to Huntsville and added the ability to handle spline curves to IGDS in short order.[3]

Nashville started digitizing the municipal maps in-house but soon realized that it had undertaken a bigger task than it could handle. After an aborted contract with an engineering firm in Atlanta, Intergraph accepted a contract to digitize the municipality's maps for the huge sum of $32,000. According to Meadlock, it ended up costing the company $200,000 to complete the work. In the process of fulfilling this obligation, the company developed important software for aligning and scaling individual map sheets.

From this one project evolved a major portion of Intergraph's subsequent business. Over the next 30 years the company probably installed several billion dollars worth of mapping systems throughout the world. It also led to a lucrative market in developing specialized mapping systems for government agencies – much of which remains classified to this day. About the same time Intergraph delivered an IGDS3 system to Fluor Corporation in Los Angeles.

Orr, of course, went on to become a leading consultant, writer and speaker in the computer graphics industry as well as a personal business associate and someone I consider a close friend.

**Moving from consulting contracts to commercial systems**

By 1975, Intergraph had honed IGDS to the point where it was a fairly respectable mapping and general drafting solution. While the company's graphics systems were still based on Tektronix storage tube graphics, it took a rather novel approach to using this technology. As mentioned elsewhere, a major drawback of storage tubes was that when a change was made to the display, such as moving or deleting an graphical element, the entire image had to be regenerated. This was particularly time

[3] Interview with Dr. Joel Orr, October 22, 2004

 

consuming if the user was viewing a small section of a drawing and wanted to view the entire drawing so as to zoom in on some other area.

Intergraph solved this problem by using two storage tube displays as components of a user station or terminal. One CRT typically displayed an overall view of the drawing or map being worked on while the second CRT displayed a smaller working area. At other times, one unit was used for alphanumeric data while the other displayed graphic information. The typical terminal had these two CRTs mounted above a large digitizer table that was the operator's primary communication device. Each workstation contained a DEC LSI-11/2 computer to control local operations. See Figure 14.2.

Need illustration of early dual screen terminal

Figure 14.2
Intergraph Model ????? Terminal with Dual Storage Tube Displays

**Intergraph in the late 1970s**

From less than $2 million in 1973, Intergraph's revenue grew to over $20 million in 1978. Although the company still did some contract programming work, especially for federal government agencies, the bulk of Intergraph's business involved interactive graphics systems, most of which incorporated the IDGS software. While the company had grown to about 200 employees by 1978, the key executives were still the original founders.

Most customers utilized their Intergraph systems for either mapping or engineering drafting applications. Major users included Commonwealth Edison, Detroit Edison, Sargent & Lundy, Bechtel, U.S. Steel, Fluor, Michigan Highway Department and Texas Highway Department. The IGDS system delivered to Texas included some of Intergraph's first photogrammetric software. Over time, this would become one of the company's technical strengths.

The company was well respected for the human factors aspects of its system design. The software was strong in mapping, drafting and database management. Although they had some manufacturing companies as customers, mechanical design and drafting was not a targeted market at this time.

**Managing explosive growth**

In the six years from 1978 to 1984 Intergraph's revenue grew by a factor of 20 to over $400 million. By 1980, the Intergraph system architecture that would dominate the engineering design and mapping markets throughout the decade and well beyond in some cases was rapidly taking shape. As mentioned earlier, there was little wasted motion in Intergraph's product development activity. Each step along the way led logically to the next. A good example was the management of attribute data for engineering drawings and maps.

Once it had established itself as the leading vendor of mapping system, Intergraph took dead aim at the AEC market and systematically began to push aside Auto-trol Technology which had been the early leader in this market, particularly for process plant engineering. Creating a instrumentation drawing for a process plant by itself is not a complex undertaking. Symbols are retrieved from a library of symbols, text is added at predefined locations on or adjacent to the symbol and inter-connecting lines are forced to snap points on the symbols. The problem is that the user ends up with a pretty picture of lines, arcs and alphanumeric text. There is no meaningful context to this data – no way to find all the 8-inch gate valves on lines carrying a specific product. This is what system implementers call "attribute" data.

There are fundamentally three ways to manage the combination of graphic and attribute data – each with its own benefits and detriments. The attribute data can be added to the graphic information in a single integrated system. This is a straightforward approach and one followed by a number of companies. On the downside, drawing files become very large and it is often difficult to keep the attribute data synchronized with the graphical elements. A second approach is to store everything in a database and extract drawing images from the database. While this eventually became an accepted technique, in the 1980 time frame computers were simply too slow to do this effectively and database software technology was still fairly immature.

The third approach was to create two parallel universes, one for graphics and one for related attribute information. This is fundamentally what Intergraph did and it worked very well for over a decade. The graphic system was the previously mentioned IGDS software which by 1980 was in its eighth incarnation. The data management function was handled by a new program, DMRS (Database Management and Retrieval System). It was a hierarchical database management system which was the preferred technology at the time. It would be a few more years before relational database technology was considered ready for prime time.

To speed up the process of finding specific information in the DMRS database, Intergraph developed a hardware device called the "File Processor" (often referred to simply as a disk scanner) that retrieved records based upon search parameters generated by application programs. The File Processor could retrieve data records based upon requests that included logical operations such as AND, OR, LESS THAN, etc. Fundamentally, it was a hardware solution to a software problem.

Eventually, software developments and faster computer hardware would negate the need for the File Processor, but for a number of years it provided Intergraph with a performance advantage over the company's competitors. A further indication of how the company looked ahead in its product development activity was that by the late 1970s it was obvious to Meadlock and his crew that a transition was underway from 16-bit computer architecture to 32-bit systems. Well before Intergraph was ready to replace the 16-bit PDP-11 computers it was then using with Digital's new, but more expensive, 32-bit VAX computers, Intergraph began converting its software to work with 32-bit data files. As a consequence, when the company did make the switch to the VAX it was able to do so with much less effort than most of its competitors experienced.

By 1980 approximately 60 percent of the company's systems business was in process plant design and heavy engineering with most of the balance mapping related. Bob Thurber headed the plant design business activity in Huntsville where all the hardware work was also done. Jim Howell handled basic mapping and land use applications, also in Huntsville, while public utility and municipal mapping was managed in Denver by Jim Hargis and Keith McDaniel. The operations side of the business was headed by Keith Schonrock with Ed Eva as the national sales manager reporting to him. Between 1978 and 1980 the company's revenue took off like a rocket growing from $20 million to over $56 million. By mid-1981, the company had installed 270 systems.

**Intergraph becomes a major player in CAD industry**

In 1981, Intergraph's product development activity seemed to switch into a higher gear. Although it was not the first CAD vendor to jump on the raster graphics bandwagon, when it do so, Intergraph did it well. The first product was a 1280 by 1024 resolution monochromatic raster display that was packaged in the company's dual-screen terminal much like the storage tube units had been earlier. It is interesting that although the dual-screen configuration had originally been implemented to overcome shortcomings of the storage tube, Intergraph continued to use this setup for many years after the company switched to raster displays. The IGDS software supported the display of eight independent views of a drawing on the two screens. The monochromatic display was followed soon afterwards by a color unit with similar resolution.

Equally significant was the company's addition of Digital's 32-bit VAX 11/780 computers to its product line in 1981. Although the VAX had been introduced in 1978, it took Intergraph some time to recompile the software to run in native mode on the VAX. PDP-11 software could run on the VAX in emulation mode but that performance left something to be desired. Moving PDP-11 software to the VAX in native mode required some coding changes and recompilation as well as a lot of testing. The switch was somewhat complicated by the fact that the original IGDS software was written about 50 percent in FORTRAN and 50 percent in PDP-11 assembly language. Likewise, high-speed interfaces for terminals had to be redesigned for maximum effectiveness.

The first Intergraph VAX systems was installed at Phillips Petroleum in Bartlesville, Oklahoma in the fall of 1981. This was part of a large order for eight VAX-based systems. An important aspect of Intergraph's introduction of VAX-based systems was that the company used a standard version of the Digital VMS operating system. This meant that third party software packages could run without modification. Of course, if the developers of these packages wanted to use Intergraph's dual-screen graphics terminals, that required some customization work. This led to cooperative relationships with third party software vendors who offered software that Intergraph did not such as structural analysis.[4]

The switch to VAX-based systems was done over some period of time. In fact, Intergraph continued to introduce new PDP-11 systems even after it began shipping VAX systems. This was especially true for lower-cost systems since the prices for VAX 11/780 computers alone started in the $200,000 range. As mentioned earlier, Intergraph had

[4] *A-E-C Automation Newsletter,* October 1981, Pg. 3

 

already switched to a 32-bit data format for IGDS and DMRS. As a result, the company's PDP-11 and VAX systems could easily share data, making the transition from 16-bit to 32-bit systems much less painful than it was for users of competitive systems.

One such low-end system was what the company called The Starter System. It consisted of a DEC PDP-11/23 minicomputer with Digital's RSX-11M operating system, an 84MB disk, a terminal with dual 19-inch monochromatic raster displays, a 36-inch by 48-inch digitizer and Intergraph's IGDS software along with several architectural space planning and drafting packages. All this for just $85,000.[5] A Hewlett-Packard 7580 pen plotter added $20,000 while substituting color displays for the monochromatic units added an additional $22,000. A mechanical design and drafting version of The Starter System was shown at AUTOFACT III in Detroit in November 1981. The company introduced color shading software around this same time that took several minutes to produce an image.

Intergraph was one of the first CAD vendors to appreciate the need to support distributed operations. The communications system it began selling in the early 1980s consisted of data concentrators that connected to the Digital UNIBUS and transferred data at rates up to 2 Mbps at distances up to 6,000 feet. The company actually called the product "Internet" well before the term came into common use.

In late 1981, 48 percent of the company's business was in mapping and land management systems and 42 percent was in AEC systems. The balance was primarily custom programming work for Federal government agencies. Intergraph was planning on entering the electronic circuit board design market with manual placement and routing software. In particular, the company planned to target prospects that used Multiwire technology for their circuit boards.

Multiwire was a technique where a machine laid overlapping insulated wires on a circuit board instead of etching traces as was done with traditional printed circuit boards. Corrections could be made to Multiwire boards with a soldering gun and jumper wires more easily than PCBs could be modified. Intergraph itself was a major user of this technology having installed $5 million of specialized equipment in 1980 and 1981 for producing Multiwire boards. While Intergraph purchased computer equipment from Digital, it produced custom circuit boards for its dual-screen workstations, the disk scanner and a vector to raster converter for driving electrostatic plotters.[6] In fact, Intergraph was beginning to become a fairly significant electronics manufacturing company at this point.

Intergraph also began the serious development of mechanical design software in the 1981 time frame. At AUTOFACT 4 held in November 1982 in Philadelphia, Intergraph demonstrated new mechanical design and manufacturing software including 5-axis machining. A new 64-bit graphics processor enabled the software to do hidden line removal operations, perform image rotation and produce shaded images very quickly. This unit also supported raster to vector conversion for scanning applications.

At the same conference Intergraph introduce a low-cost VAX 11-730 system that sold for $145,000 with one workstation and mechanical design and drafting software. The

[5] *A-E-C Automation Newsletter*, October 1981, Pg. 1
[6] *Anderson Report*, October 1981, Pg. 3

company also previewed a new InterAct workstation powered by a Motorola 68000 microprocessor.[7]

There were two versions of this new InterAct workstation. The DSP041 used two monochromatic raster displays while the DSP042 had one monochromatic display and one 256-color display. The 68000-based display processor with its 68KB memory handled functions such as pan, zoom and rotate locally once the graphic image was transferred from the VAX memory. View transformations of fairly complex images typically took less than two seconds. The company was also working on an array processor than would be able to produce images of complex three-dimensional models with hidden lines removed ten to twenty times faster than could be done in software on a VAX 11/780.

**Bechtel validates system productivity**

The company went public in April 1981. Intergraph's revenues grew to $91 million in 1981 and $156 million the following year. With VAX systems selling for over $100,000 per seat, the company's growth was being powered by sales to large engineering organizations.

Typical was Bechtel's Los Angeles Power Division (LAPD). By May 1983, this organization had 14 Intergraph systems at five different sites with a total of 84 workstations committed to power plant design applications. By 1983 Intergraph had replaced Auto-trol Technology as Bechtel's primary CAD vendor.

Bechtel was seeing significant productivity improvements using these systems. Pipe hanger design went from four hours to 15 minutes while, at least in one case, a 30-hour structural frame design was done in 30 minutes. Much of this performance was accomplished through the use of specialized IGDS add-ons developed by Bechtel. One example was BISEPS (Bechtel Interactive System for Engineering of Pipe Supports).[8]

**Establishing strong position in the mapping market**

Many entrepreneurial organizations fail because the founders attempt to keep these companies within their original comfort zone rather than adapt to the needs of the marketplace. Intergraph's founders had backgrounds predominately in space related technology such as NASA's Apollo program. That did stop them, however, from taking Intergraph into new markets they saw as emerging opportunities. The market that probably did more to define Intergraph than any other was what can generally be described as mapping. or geographic information systems (GIS).

GIS does not refer to a single application. Rather it is a broad spectrum of applications that have one thing in common – managing large volumes of spatially related data. One aspect of this market that Intergraph came to dominate was the production of topographic maps, predominately for military and non-military government agencies. Another market segment was the data collection and preparation of maps for utilities containing detailed information relating to physical assets. The latter area soon became known as Automated Mapping/Facility Management (AM/FM). These maps were far different from those used for planning purposes where the information being recorded and displayed referred more to types of land use such as zoning data or

[7] *CAD/CAM Alert*, December 1982, Pg. 2
[8] *A-E-C Automation Newsletter*, May 1983, Pg. 1

 

population densities. This latter area is referred to as thematic mapping and is a market segment that never was a particularly high priority at Intergraph.

One of Intergraph's first significant mapping customers was Southern Bell.[9] Working with AT&T and Bell Labs, Intergraph implemented a continuous facilities model using the company's DMRS and IGDS products. This software was used to model Southern Bell's outside plant – that portion of the telephone network not inside its switching centers. It was basically a database management solution driven by graphics although inquiries could be made from alphanumeric terminals. Changes to the telephone network entered via these alphanumeric terminals were immediately reflected in the graphic views of the data.

Another pressing need for mapping software in the early 1980s was in the oil and gas industry for managing exploration and production data. Just a few years earlier, the United States had experienced a severe oil shortage that resulted in long lines at the local gas station. Intergraph recognized the need for new technology to help in this area and plunged in to provide solutions to the industry. It turned out that many of the application modules developed to support energy companies were also useful for other mapping customers. These packages included software to:

- Digitize paper maps and photographic images to produce a spatial database.
- Covert data from one coordinate system to another.
- Adjust digitized data to compensate for paper shrinkage and to match one map sheet to another.
- Produce digital contour maps from grids of data points (this was commonly called digital terrain modeling).
- Select data based upon proximity to linear or area features.
- Digitize and process specialized data such as oil well logs and seismic results.

Product development activities at Intergraph during the preceding ten years had positioned Intergraph very well to pursue this market. The separation of graphics and data management functions into two separate programs, IGDS and DMRS, proved to be an effective way to manage the mass of data these applications involved while the company's proprietary disk scanner resulted in fast interactive response times. The use of industry standard Digital VAX computers made it relatively easy for oil and gas companies to integrate their Intergraph systems with other data processing resources. Finally, the dual-screen terminals, especially the color raster versions, facilitated the viewing of these large data files.[10]

Although Calma, Computervision, Auto-trol Technology and even Applicon offered mapping applications, none of these competitors focused on the market to the extent that Intergraph did. Probably the company's most serious competition was a Houston based company, Synercom. The latter company had good technology but never was able to achieve the market recognition that Intergraph did. In the planning area, the major competition would eventually turn out to be Environmental Systems Research Institute, Inc. (ESRI), but in the early 1980s, it had yet to achieve critical mass.

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[9] Southern bell eventually became BellSouth and then in 2006, merged with AT&T.
[10] *A-E-C Automation Newsletter*, November 1981, Pg. 6

 

Exploration and production mapping systems also provided Intergraph with an opportunity to expand its international presence, especially in the Middle East. This would eventually turn out to be a major source of revenue for the company. As we will see later, by 2004, Spatial Information Management as Intergraph now calls it, generated directly or indirectly 75 percent of the company's revenue.

**New generation plant design software**

As part of the company's plan to develop a new process plant design system, Intergraph teamed up with a Houston company, Zydex Engineering, Inc. in late 1981, to develop a new plant design system. Zydex was run by Eduardo (Ed) Zorrilla. This joint development project led to what eventually became known as Intergraph's Plant Design System (PDS). The software was intended to provide an comprehensive interactive three-dimensional capability for complex process plants including design, drafting, material take-off, and visualization. Zydex developed the specifications for PDS while Intergraph personnel did the actual software implementation.

The first public demonstration of PDS was at the Petro Expo '85 show in Houston in March 1985. The first modules mostly involved two-dimensional drafting applications such as P&IDs and Instrumentation Loop Diagrams. I saw a demonstration of the software in April 1985 at NCGA-85 in Dallas. My observations at the time were:

- The new software involved more keyboard activity than Intergraph's earlier plant design software.
- Performance using a VAX 11/750 and an InterAct dual screen workstation was not particularly impressive except for generating shaded images of the plant model. The latter task was facilitated by the use of Intergraph's Graphics Processor described earlier.
- Fittings were inserted by first routing the pipe and then inserted specification defined fittings in a batch operation. During the demo, it took three minutes to insert eight fittings. Inserting fittings on a vessel took just a few seconds, however.
- The system did not appear easy to use. During the demonstration I watched, the application engineer lost his orientation in the model and had to stop, log off, reload the model and then continue. His last few operations were lost when he logged off.[11]

By mid-1986 Intergraph had invested over $8 million in developing the complete application suite.[12] PDS represented a new approach to engineering design, one in which the management of design data was treated as important as if not more so than the graphical design of the physical plant. Descriptive information was stored in a manner that facilitated multiple applications sharing the same data.

The underlying concept was that once a data element was defined, perhaps in a P&ID (Process and Instrumentation Diagram), that information could be used to produce other drawings such as instrument loop diagrams or to verify that process elements were not left out of the actual piping design. This held whether the application involved two-dimensional schematic data or three-dimensional models of the plant. Prior systems

[11] Author's personal notes
[12] *Anderson Report*, August 1986, Pg. 4

 

tended to treat each application's data separately and transferring information from one task to another was a "hit or miss" affair.

As implemented, PDS actually stored information in three interrelated databases.

- Reference Database – contained information relative to industry design codes, vendors' catalog data, job specifications, symbol libraries, etc.
- Task Database – used to store working data associated with active design tasks prior to that aspect of the design being "approved."
- Master Database – repository for approved project data. Once a portion of the plant design was stored in the Mater Database, special procedures were required before that data could be changed.

Specific programs implemented in PDS handled the following tasks:

- Process and Instrumentation Diagrams (Included a library of 1,000 symbols)
- Instrument Diagrams
- Instrument Loop Drawings
- Equipment Design
- Plant Layout
- Structural Modeling (analysis handled by Intergraph-Rand Micas or third party programs)
- Piping (Included a library of 75,000 components)
- Electrical Raceway Design
- HVAC

The basic user interface to PDS was done with IGDS which by mid-1986 encompassed over 800 man-years of development effort. The software was implemented on the Digital VAX computer using the VMS operating system. Orthographic piping drawings were produced by selecting portions of the plant model, eliminating hidden lines and then using IGDS to put the finishing touches on the drawings.[13]

While one group of Intergraph programmers was preparing PDS for formal release as a VAX-based system in mid-1986, other Intergraph software groups were hard at work preparing a new generation of applications for the company's UNIX workstations then under development. PDS would remain a VAX-based application longer than any other comparable program sold by Intergraph and it would not be until the early 1990s before it would be ported to UNIX.

In August 1995, Intergraph filed a legal action seeking to dissolve its business arrangement with Zydex. Intergraph wanted to be able to continue selling PDS without having to pay Zydex on-going royalties which supposedly were in the range of 30 percent of the software's sales price. Zydex filed a counterclaim several months later alleging wrongful dissolution of the business relationship, seeking both sole ownership of PDS and significant compensatory and punitive damages. Needless to say, this would have effectively put Intergraph out of the plant design business if the court had sided with Zydex.

After nearly two years of litigation, the companies agreed to settle the dispute in 1997, but failed to agree on certain terms of the settlement. In September 1997, the court issued an order resolving the disputed issues and dismissed the case. The settlement

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[13] *A-E-C Automation Newsletter*, June/July 1986, Pg. 14

involved Intergraph acquiring Zydex for $24.8 million. The closing under these terms never took place and finally in November a hearing was held during which the judge ordered both parties to sign the closing documents.

The documents were finally executed by both parties, but Zydex still wanted to take one more shot at Intergraph and indicated they might appeal the judge's order.[14] In order to put this dispute behind it, Intergraph agreed to increase the payment to $26.3 million and the deal was finally consummated in January 1998. PDS software sales in 1997 amounted to about $45 million.[15]

**Intergraph in the mid-1980s**

The 1980s were the go-go years for Intergraph. The company was starting to pursue nearly every aspect of automated design and drafting. This even included architectural applications, an market segment the company would pull out of in the late 1990s with Meadlock complaining that it was impossible to make a profit selling to architectural firms. Typical applications included Structural Steel Detailing and Reinforced Concrete Detailing which sold for $10,000 each. Remember, Intergraph's software prices were on a per system basis and at this point in time, the company was claiming that a VAX 11/785 could support up to 20 terminals.

In the early 1980s, Intergraph started getting carried away with executive titles. Jim Meadlock was, of course, president and CEO. Below him were eight executive vice presidents: Keith Schonrock, Jim Taylor, Nancy Meadlock, John Thorington, Roland Brown, Allan Wilson and Willam Zarecor.[16] Nancy Meadlock was taking on increased responsibilities at Intergraph as executive vice president of administration and was clearly a power behind the throne. About the same time, Rick Lussier became vice president of sales. He held this job until early 1985 when he left the company and was replaced by Howard Fisher. Both had earlier worked with me at Tektronix.

Intergraph eliminated most 16-bit Digital PDP-11 systems from its product line by mid-1983 and focused on the 32-bit VAX machines. By the fall of 1983, Digital had shipped over 500 VAX systems to Intergraph.[17] One exception was the low cost Innovator II which was targeted for use in architectural applications that used a Digital PDP-11/23 computer.

Architectural software product management was under the direction of Al Kemper who reported to George Stienke[18], vice president of product marketing. Kemper was a well respected author[19] on the subject of architectural design and had worked at Ralph M. Parsons as well as Tricad, a Calma spinoff. Kemper's master plan envisioned the use of Intergraph software for everything from the preparation of massing studies to CAD-generated perspective site views, walkthroughs and what would eventually come to be called "urban simulation." Kemper also saw the need for using the computer to

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[14] *A-E-C Automation Newsletter*, December 1997, Pg. 4
[15] Intergraph 2000 Annual Report, Pg. 60
[16] *Anderson Report*, January 1983, Pg. 8
[17] *Anderson Report*, September 1983, Pg. 2
[18] Steinke left Intergraph in March 1985 to become vice president of sales and marketing at Cognition, a company founded by Philippe Villars who had also been one of the founders of Computervision.
[19] *Architectural Handbook – Environmental Analysis, Architectural Programming, Design and Technology, and Construction,* Wiley Interscience, 1980

manage project workflow, an area that would attract tremendous focus in the late 1990s as the use of the Internet took off.[20]

In the mechanical area, a key development was an agreement signed with Xerox Corporation in January 1984 under which the two companies planned to work together in the development of surface and solids modeling, kinematics analysis, robotics and enhanced numerical control.[21] This was followed by the introduction of a mechanism modeling package two months later that produced data that could be used by third-party analysis programs.

By mid-1984, Intergraph was firing on all cylinders. It had increased its market share in 1983 to 14.7 percent on $252 million in sales. Only Computervision and IBM had larger sales in this industry. Intergraph participated in every segment of the CAD industry with sales broken down as follows:

| | |
|---|---|
| AEC | 43 percent |
| Mapping | 31 percent |
| Mechanical | 13 percent |
| Electronics | 2 percent |
| Technical Publications | 2 Percent |

**MicroStation comes on the scene**

(As previously mentioned, the detailed story of the Bentley brothers, Bentley Systems Incorporated (BSI) and MicroStation is contained in Chapter 10 although some of it is repeated here.)

Intergraph's pricing model until it began selling its own Clipper-based workstations, was to license the IGDS and DMRS software on a per CPU basis. When a company purchased a VAX 11/780 system, it could attach as many terminals as the computer could physically support. The limit really was based on what was the acceptable level of performance for the type of work the customer was doing. There was just one catch. The software only worked with Intergraph manufacturer terminals and these were fairly expensive. Like many other turnkey CAD vendors at the time, the bulk of Intergraph's revenue came from selling hardware and software was seen as the means that enabled the company to sell hardware.

One of Intergraph's major customers in the early 1980s was DuPont in Wilmington, Delaware. Keith Bentley had gone to work at DuPont after receiving an MS degree in electrical engineering from University of Florida. DuPont was using its Intergraph systems for producing process plant electrical diagrams. Usage, however, was limited by the high per seat cost of adding more capacity. Bentley believed that there was a lower cost alternative and set out on his own time to develop a package called PseudoStation. It enabled someone to use Intergraph's CAD software from a low-cost Digital VT-100 terminal equipped with a graphics card or a Tektronix storage tube terminal such as a 4014. PseudoStation proved to be particularly cost effective when DuPont designers simply wanted to make changes to existing drawings such as revising some text on a drawing.

In 1983, Keith Bentley left DuPont to work with his brother Barry in California at a company called Dynamic Solutions. Before leaving Dupont, Bentley negotiated an

[20] *A-E-C Automation Newsletter*, May 1984, Pg. 3
[21] *CAD/CAM Alert*, January 1984, Pg. 7

agreement with Dupont under which he received marketing rights to the software in return for which he would provide technical support to the company's PseudoStation users. On the way to California, he stopped in Huntsville and offered the software to Intergraph. According to Bentley, "I would have sold [PseudoStation] to Intergraph for $5,000, and that would have been that. [That I didn't] is one of a series of lucky coincidences….."[22]

Los Angeles had a large number of Intergraph installations and soon Keith and Barry Bentley found a receptive audience for PseudoStation. Keith founded Bentley Systems Inc. and arranged to have Dynamic Solutions market the software in exchange for work he did on that company's software. Soon Keith and Barry sold their interest in Dynamic Solutions and relocated to the Philadelphia area where they were joined by brother Scott and Ray. Within a short time they sold over 350 copies of the terminal-based PseudoStation software.

After relocating to Philadelphia, Keith became convinced that what Intergraph was doing on a VAX, he could do on a IBM PC/AT. This new version of the software was soon known as MicroStation. In January 1987 Intergraph purchased a 50 percent interest in Bentley Systems for $3 million and announced that MicroStation would be marketed by Intergraph on both UNIX and PC platforms.

**Micro IGDS – an alternative to MicroStation**

Bentley Systems was not the first PC CAD software company Intergraph acquired an interest in. CNR Research was started by two former employees of Bechtel Power Corporation in Ann Arbor, Michigan, Antonio Robinson and Erdwing Coronado. Robinson had been a system engineer for Bechtel while Coronado was a senior programmer-analyst. When Bechtel announced plans to shut down its Ann Arbor office in 1984, the two decided to start their own software company, CNR Research, with Robinson as president and Coronado as vice president of R&D.

Initially, the two focused on providing CAD/CAM consulting based on their knowledge of Intergraph systems and Digital hardware. In April, 1985, the two decided to create a two-dimensional drafting package compatible with Intergraph's IGDS. Called C-CADD, it ran under both MS-DOS and UNIX and implemented the equivalent of about 30 to 40 percent of the commands in IGDS. According to *A-E-C Automation Newsletter*, this represented over 90 percent of the functionality in IGDS. The software sold for $3,000 per copy, a little more expensive than AutoCAD.

C-CADD was written in C, a fairly new programming language at the time and its files were compatible with Intergraph's IGDS file structure so no translation was necessary. Competitors, including VersaCAD and Autodesk, were promoting the fact that they had software available for translating Intergraph drawing files. In May 1986, Intergraph acquired a 50 percent equity interest in CNR Research. Under the new relationship, CNR continued to market the PC version of C-CADD through its existing reseller channel (eight companies at the time) while Intergraph marketed the UNIX version, now known as MicroIGDS, through it sales organization.[23] Once Intergraph

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[22] Solomon, R. E., "Those fabulous Bentley Brothers, MicroStation's building blocks," *MicroStation Manager*, June 1992, Pg. 76

[23] *A-E-C Automation Newsletter*, June/July 1986, Pg. 28

acquired an interest in Bentley, it lost interest in marketing the UNIX version of MicroGDS and CNR Research and C-CADD simply faded away.

**Intergraph software in the mid-1980s**

As mentioned earlier, Intergraph's primary graphics software package was IGDS. Data was maintained in either a two-dimensional or three-dimensional format with some difficulty in moving it from one state to the other. One of the major limitations was that an active drawing could only have 63 layers of data. This was far less than competitive systems which typically could store 256 or more layers and in some cases an unlimited number of layers. In addition, up to three reference drawings each with its own 63 layers could be overlaid with the base drawing. Another shortcoming was the fact that IGDS used a 32-bit fixed point format at a time when other vendors had switched or were in the process of switching to 32-bit and 64-bit floating point data. It was a trade-off between performance and precision.

IGDS was particularly efficient when being used for two-dimensional drafting. One reason for this was that the drawing data did not carry with it three-dimensional data that was not needed as did some competing system. The software generated up to eight independent views of a drawing and displayed up to four on each screen of a double-screen workstation. A macro language called User Command enabled users to combine a series of tasks in a single command. The primary user interface was a hard copy menu on a large digitizer located in front of the terminal's display(s). For a user to change the layout of the menu or to add new commands required the knowledge of FORTRAN programming. By mid-1985, the interface was in the process of being changed to more on-screen menus and "fill in the blank" dialog boxes.

Most CAD packages then on the market stored attribute data as part of the drawing file. Intergraph took a different approach and stored this data in a separate file which was managed by the previously mentioned DMRS (Data Management Retrieval System)software. DMRS primarily used a CODASYL compliant hierarchical data structure although by mid-1985, Intergraph was incorporating some relational technology into the package.

DMRS was not required to do straight-forward CAD tasks such as drafting and many customers opted not to use it because of the time required to learn the software. One shortcoming was that a user could not back up the data associated with a single drawing file but had to back up the entire DMRS database. This might have worked well for a utility mapping customer but it really was awkward for the typical architecture or engineering organization to use.

Although DMRS could be used without Intergraph's File Processor, that hardware greatly improved performance when it was part of a VAX configuration. The linkage between DMRS and IGDS was managed by a software module called Attribute Services. The price of the data management software as well as IGDS was bundled in with the cost of the VAX computer at the heart of all Intergraph systems at this time.

Like all other CAD vendors, Intergraph was also becoming interested in solids modeling. Its implementation of solids technology, Solids Modeler, was tightly coupled to IGDS. Wire frame and surface defined geometry could be used to create solids. The Graphics Processor was required in order to utilize this software.

 

Intergraph had perhaps the largest array of applications software of any vendor in the industry at this time. These application fell in several broad categories.

- Process plant design.
- Engineering design.
- Architecture.
- Mapping.
- Petroleum exploration and production.
- Mechanical engineering.
- Electrical engineering.
- Technical illustration.

Although the open architecture of the company's VAX systems enabled outside parties to develop software to run on Intergraph systems, there were few such packages. Part of this was due to the fact that the company did not particularly encourage third-party developers and part was due to fact that these developers would have had to purchase a VAX system from Intergraph in order to do any development work. Complicating the development of third-party software was the fact that Intergraph fine tuned the VAX VMS operating system to give high priority to the company's workstations. Outside developers had to understand what had been done and adapt their software to these modifications or their software would not operate effectively.

**Typical prices**

Some of the typical Intergraph prices as of mid-1985 were:

| | |
|---|---|
| • VAX 11/750 CPU with a floating-point accelerator, 2MB of memory, an 84MB disk[24], tape drive, File Processor, console and IGDS and DMRS software | $195,000 |
| • INF096 Graphics Processor | 40,000 |
| • Additional VAX memory in 0.5MB increments | 5,000 |
| • InterPro 32 (monochromatic) | 20,000 |
| • InterAct color workstation | 48,000 |
| • Architectural drafting software | 10,000 |
| • Base map digitizing | 2,000 |
| • Drawing management | 4,000 |
| • Finite element modeling | 10,000 |
| • Mechanical design and drafting | 10,000 |
| • Solids modeling | 20,000 |
| • Numerical control | 10,000 |

While some of these software prices seem high, it should be remembered that these were the cost per VAX system. If a VAX 11/785 had a ten workstations doing mechanical design then the cost of the application software per user was only $1,000.

**A new generation of workstations**

In 1983 Intergraph began demonstrating new single screen InterPro and dual screen InterAct terminals that utilized Motorola's 68000 microprocessor. Initially, the

[24] A single 86MB disk drive left very little room for drawing files since the VMS operating system and the IGDS and DMRS software required nearly 80MB by itself.

 

InterPro was just available as a monochromatic unit. The first InterPro unit was the Model DSP046 with a price of $25,000.[25] A color InterPro was introduced in mid-1984 for $42,000. The DSP052 InterAct had dual monochromatic screens while the DSP055 had one monochromatic screen and one color. All these units had 1280 by 1024 resolution. The InterAct used a structural foam type of construction and provided substantial operator control over the height and angle of the displays and the digitizer table.

By 1984 it was fairly clear to most executives in the CAD industry that the future was with networked workstations rather than minicomputer-based systems. While competitors such as Auto-trol Technology, Calma, and SDRC were making the transition to commercially available workstations from Apollo and Sun Microsystems, Intergraph had started down the path of building its own workstations and, in effect, becoming a vendor of commercial workstations as well as CAD systems. It was clear that Intergraph saw networked workstations as the wave of the future. It just took the company longer to get there than it would have liked. In November 1982, Jim Meadlock had been quoted as saying "If I were starting a new company today, I would build a standalone workstation operating in a network."[26]

In September 1984 Intergraph announced the single screen InterPro 32 workstation which was intended to use the National Semiconductor 32032 microprocessor as well as an Intel 80186 microprocessor. It was designed to run UNIX on the 32032 and MS/DOS on the 80186 although not both at the same time. Initially, the company said that deliveries would start in the first quarter of 1985. The InterPro 32 was intended to function as a stand-alone UNIX workstation, as a terminal for Intergraph's existing VAX-based systems, as a terminal emulator for devices such as the Tektronix 4014 or as a IBM-compatible PC.

The price for the hardware was set at $20,000 which, given the intended capabilities, appeared to be very competitive.[27] There was a major misconception at the time, however. Although Intergraph did not claim that the InterPro 32 would be able to directly execute IGDS software, the impression among many potential prospects was that it would do so. The initial InterPro 32 had a 15-inch color monitor with 1184 by 884 resolution. It displayed 64 colors from a palette of 4,096. It had a base memory of 1.75MB upgradable to 4MB. It also had as 26MB hard disk and a floppy disk as well as a 64-bit floating point processor.

Numerous other workstation manufacturers with names we have long since forgotten such as Syte, Saber and Mosaic, planned to introduce workstations in this time period using the 32032 microprocessor. The 32032 nomenclature referred to the 32-bit instruction size and 32-bit data bus architecture. National Semiconductor had not yet produced deliverable 32032 chips and was providing its OEM customers the 32016 with a 16-bit data architecture as an interim microprocessor. The InterPro 32 based on the 32016 was slow compared to competitive products from Apollo and Sun. National was never able to produce 32032s in quantity and eventually most of the workstations vendors developing product lines dependent on this chip went out of business.

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[25] Author's personal notes

[26] Author's personal notes.

[27] *Anderson Report*, October 1984, Pg. 1

At the same time that Intergraph announced the InterPro 32, it also announced support for Digital's MicroVAX II which would support up to four workstations. The basic computer was priced from $40,000 to $60,000 with workstations extra. Packaged by Intergraph as the Model 250 it was also referred to as the Micro II. Deliveries were scheduled for the second quarter of 1985. One problem with the MicroVAX was that Digital replaced the UNIBUS used on prior VAX system with a slower Q-BUS. Intergraph, in turn, replaced the Q-BUS with a data bus of its own design called the INTERBUS which had a capacity of 13.3 Mbps. The InterPro 32 connected to VAX systems via an Ethernet link. In what was perhaps a strategic mistake, Intergraph chose to use Xerox's XNS Ethernet protocol rather than the TCP/IP Ethernet protocol that most other computer manufacturers were using. Perhaps this was done because Xerox was emerging as a major Intergraph customer.

At the AUTOFACT-6 Conference in Anaheim, California in October 1984 the units on display were unable to execute IGDS software on a VAX computer. A complete one-station system consisting of a MicroVAX II and an InterPro 32 with IGDS, DMRS and architectural drafting software was eventually launched in June 1985 at a somewhat expensive $94,000.[28] A dual MicroVAX II system called the 252 was introduced in August 1986. The MicroVAX system did not support either Intergraph's File Processor or Graphics Processor.

Intergraph began shipping InterPro 32 units based on the 32016 in early 1985 with the commitment that they would be upgraded to the 32032 as soon as that microprocessor was available.[29] The company also said it would provide IGDS software on the InterPro 32 along with applications such as schematic drafting. This never occurred as the company shifted its focus to MicroStation for UNIX platforms. Some stand-alone UNIX-based applications were available including the FEA software Intergraph had obtained when it acquired the Rand Group.

It was still not clear as of April 1985 if Intergraph intended to completely replace its VAX systems with the new UNIX workstations.[30] By the SYSTEMS-85 conference in June 1985 in Anaheim, California Intergraph was able to demonstrate the InterPro 32 as a terminal running IGDS on both a VAX 11/750 and on a MicroVAX II. Intergraph's UNIX implementation supported multi-tasking with each task running in its own window. Separate tasks could be logged on to different VAX systems. As an example, a user could be running a complex analysis task on a VAX 11/785 while doing interactive drafting on a MicroVAX II.

Eventually, Intergraph got tired of waiting for National to deliver the 32032 and switched to Fairchild Semiconductor's Clipper microprocessor. This move would eventually radically change the fortunes of Intergraph but that is a story covered elsewhere in this chapter. In mid-1986, Intergraph introduced ten Clipper-based workstations and two servers including InterPro, InterAct, InterView and InterServe units.

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[28] Author's personal notes

[29] Some analysts expected that the volume of InterPro 32s would take off during the second half of 1985. Jay Cooper of F. Eberstadt & Company wrote in a June 18, 1985 report that he expected Intergraph to ship 900 units during the third quarter and 2,400 units during the fourth quarter. He also projected that Intergraph would generate $314 million in mechanical systems revenue in 1986, a number the company never came close to.

[30] Author's personal notes

 

The difference between these workstations was that the InterPro was a desktop unit while the InterAct used Intergraph's traditional dual screen packaging. The InterView was a limited function version of the Interpro that was intended to be used for data entry and graphic viewing. There was also a limited production unit called the InterMap that was intended for use with photogrammetry equipment. These systems all ran Intergraph's implementation of UNIX called CLIX. The InterPro and InterAct workstations were priced from $29,000 to $72,000 while the InterServe servers were priced from $22,000 to $29,000.

The InterPro units were initially intended to be used as either a VAX terminal or as a stand-alone workstation while the InterActs were more expensive stand-alone units with high performance graphics. Intergraph used the Weitek floating point engine in these units with a display processor that could support 512 colors from a palette of 16 million and display 100,000 vectors per second. This was about as good as anything that workstation manufacturers such as Sun and Apollo could offer. The InterPro 32C, introduced in July 1986, offered five MIPS performance for just $25,000. At the time, this was a significant level of performance for a moderate price tag. Both 15-inch and 19-inch displays were available on the InterPro 32C.

**The transition to UNIX**

A significant problem that would plague Intergraph for several years was that customers, especially large government agencies, wanted industry-standard UNIX systems rather than proprietary systems such as Digital VAX computers. The UNIX version of MicroStation was the primary graphics system for the company's new workstations. The major problem the company faced was converting its vast array of applications that had been developed to work with IGDS and DMRS to now work with MicroStation. This was a substantial task and it was the late 1980s before the bulk of the work was completed.

While this transition was proceeding Intergraph had to install a mixture of VAX and UNIX systems at many customer locations since some applications were only available on the older machines. In other cases, the company was forced to provide customers with VAX systems which were subsequently swapped out for Clipper-based UNIX workstations.

One aspect of moving from VAX-based IGDS and DMRS to MicroStation on the new UNIX workstations was the need to replace the hardware functionality of the DSK062 File Processor with its software equivalent. To a lesser extent the same applied to converting tasks handled by the INF096 and INF103 Graphics Processors with either UNIX software or comparable functionality incorporated into the workstation's graphics hardware.

**Pursuing the mechanical CAD market**

By the early 1980s it was clear that the largest overall segment of the CAD industry going forward would be the mechanical sector. The first Intergraph systems were sold into this market in 1982. Intergraph's early software for this market was simply its IGDS software with mechanical drafting and manufacturing applications built on top. Starting out somewhat slowly in the mechanical market, Intergraph developed some fairly decent NC software by mid-1985. In particular, the company took advantage of its ability to rapidly display color shaded surfaces to show NC tool paths on top of these shaded surfaces.

The software was mostly on-screen menu driven with extensive use of dialog boxes and icons. The company's three-dimension modeling software handled most types of mathematical surfaces including planes, cylinders, ruled surfaces, NURBS, and Bezier surfaces. Intergraph, however, was always playing catch-up in the mechanical software arena and never provided its mechanical R&D staff with sufficient resources to dominate this software arena like it did mapping and AEC. Customers used the company's mechanical software primarily for designing industrial machinery rather than stylized automotive or consumer products although Intergraph was always able to provide examples of the latter type of user for marketing purposes.

Trying to be all things to all people, Intergraph began developing robotics software with GMF Robotics Corporation in early 1984 and technical illustration software around the same time. The previously mentioned Xerox contract, worth $20 million over three years, was a good example that the company could be serious about this market when it wanted to be. Around the same time, Intergraph introduced the Mechanism Modeling System (MEMS) which interfaced to Mechanical Dynamics' ADAMS and DRAMS software.

**Getting serious about electronic design**

As mentioned earlier, Intergraph had begun offering software that facilitated the graphical layout of circuit boards several years earlier. Meanwhile, the electronics design industry was making the transition to more automated techniques for designing electronic circuits, a field that soon became known as Electronic Design Automation or EDA. This was a new generation of software, not simply CAD software adapted to the design of circuit boards and integrated circuits.

Intergraph's management recognized that EDA was a new specialty field and that new software would have to be developed by individuals who understood what was involved. Rather than setting up such as group in Huntsville, in September 1984 Intergraph provided seed funding for Tangent, a new EDA software company in California. It invested $2 million up front for a 50 percent interest in this new six-person firm and provided it with a $4 million line of credit.

In June 1985, Intergraph announced two EDA products. The first, which ran on the InterPro 32, supported logic capture, rules checking, timing analysis, as well as logic and fault simulation. According to the *Anderson* Report, the software sold for $5,000 per seat. The other package, TANCELL, handled the physical design of semi-custom integrated circuits. It ran on a VAX computer and sold for $75,000 per system.[31]

Eventually, Tangent was acquired by Cadence Design Systems in early 1989 with part of the deal envisioning Cadence porting its EDA software to Intergraph's Clipper workstations. To the best of my knowledge, this never happened.

In December 1990, Intergraph acquired Dazix, the company that was formed in May 1989 as a result of the merger of Daisy and CADnetix. Within months of being formed, Dazix was in deep financial trouble and filed for Chapter 11 bankruptcy. This was in spite of having $90 million in revenue in 1989.

[31] *Anderson Report*, July 1985, Pg. 1

 

On the surface, it looked as if Intergraph had gotten a bargain since it paid just $14 million for the company, $10 million in cash and $4 million in stock. One of the underlying reasons for Intergraph making this move was to be able to offer customers combined electronic and mechanical design solutions.

Dazix had recently ported its software to Sun workstations and Intergraph stated in early January, 1991 that it would do the same with its existing electronic design packages. The statement was made, however, that there were no plans to convert the company's mechanical software to the Sun platform. That generated concern among users and tended to decrease the attractiveness of Intergraph's combined electronic and mechanical solution since Sun computers were rapidly becoming the preferred workstation platform within the electronics industry.

If nothing else, Intergraph knew how to respond to rumblings among its customers. In February, the company signed an OEM agreement with Sun worth $150 million over three years. This was followed shortly thereafter with the announcement that both MicroStation and I/EMS (the company's new mechanical design software) would be ported to the Sun platform, MicroStation by the first quarter of 1992 and I/EMS by the second quarter. Other than MicroStation and the mechanical product line, however, there were no plans to port other Intergraph software to Sun computers. Meadlock summed up the situation:

> "Today's mechanical engineering marketplace demands the flexibility of a dual platform offering. Our customers tell us they want to be able to easily integrate the electronic and mechanical applications. Having already made the commitment to support our Dazix customers with both Clipper and SPARC workstations, it was a natural decision to move the mechanical product offerings onto the SPARC platform."[32]

Initially, the acquired company was referred to as Dazix, An Intergraph Company. Intergraph continued to pour money into the EDA market. In July 1991, it purchased an 18 percent interest in Silvar Lisco for $1.1 million in cash. By early 1992, the EDA portion of Intergraph was generating over $100 million in annual revenues. Subsequently, the Dazix name was changed to VeriBest. This operation never made any money for Intergraph, however, and it was eventually sold to Mentor Graphics in October 1999 for $11 million.[33] According to *Electronic News,* Intergraph had planned to take Veribest public, but a continuous string of unprofitable quarters, driven by a failure to achieve critical mass, hastened the company's decision to sell VeriBest. Jim Meadlock was quoted as stating:

> "While we think we had an extremely good set of products, we had a hard time making any money. We did set up Veribest to make it an independent company, but we never quite got the economy of scale to be there. (An initial public offering) was the hope, but we finally decided that we weren't going to make it on our own."[34]

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[32] *Anderson Report,* April 1991, Pg. 3
[33] *Intergraph 1999 Annual Report,* Pg.17
[34] *Electronic News,* November 8, 1999

## Intergraph acquires Rand Group

Intergraph added structural analysis software to its product line by licensing a finite element analysis package called Rand-Micas developed by Len Rand. Intergraph named it Intergraph/Rand-Micas and sold it for $25,000 per system. In 1985, Intergraph acquired Rand's Dallas-based company and he went to work for them as president of a new organization called Intergraph-Rand Corporation.

## Intergraph becomes a billion dollar company

In 1985, Intergraph became the second largest CAD vendor after IBM, pushing Computervision into third place. From $526 million in 1985, the company's revenues soared to over $1 billion in 1990. By 1992 the company had revenues of $1.18 billion and ranked Number 315 in the *Fortune 500* for that year. That this strong growth came about as other vendors including Auto-trol Technology, Computervision and Applicon stumbled during the latter 1980s did not surprise knowledgeable industry observers. Ken Anderson probably summed it up best in the August 1986 issue of the *Anderson Report*.

> "Competitors and some financial analysts wait for Intergraph to stumble in its relentless growth. Meanwhile the crew in Huntsville seems almost oblivious to outside pressures as they focus on expanding market share across all CAD/CAM applications. Intergraph has a three pronged strategy for growth: internal product development, strategic alliances and acquisition. Two issues are key in the continuing saga of this premier company. Intergraph totally dominates the mapping application and they make the most efficient use of R & D investment of any company in CAD/CAM. This R & D prowess provides a continuing stream of new hardware and software products. Jim Meadlock, Pres. has become a legend in his ability to manage growth and at the same time elicit a high level of dedication from the people at Intergraph."[35]

A critical aspect of Intergraph's product strategy was the selection of Fairchild's Clipper microprocessor to power its workstations at a time when most of the industry heavyweights were going with Motorola's 68020 microprocessor. In mid 1986, the Clipper was perhaps five times as fast as the 68020 but it was an unproven product. One of the issues driving Intergraph to move as rapidly as possible to its own workstations was that Digital was in the process of reducing the discounts it provided to OEM customers. This made the resale of Digital computers less attractive to companies such as Intergraph.

As mentioned above, the major challenge facing Intergraph in mid-1986 was making the transition from a VAX VMS host-based software environment to a UNIX environment using networked workstations and servers. While developing the new UNIX software, Intergraph had to continue maintaining and adding some enhancements to its VAX software in order to keep its existing customers happy. For some time, the company's customers seemed to be content with using the new workstations as VAX terminals while Intergraph chipped away at converting its software products.

[35] *Anderson Report*, August 1986, Pg. 3

Intergraph planned to use this software transition as an opportunity to implement some new technologies. In particular, the company began developing software that used "object-oriented" software techniques. Eventually, this would become fairly standard within the software community but in 1986 it was still a fairly radical concept.

At the time, Intergraph's shift to UNIX workstations looked like a smart move and for a number of years it was. Another option existed at the time that might have proven more advantageous in the long run. That was the emergence of the PC as a serious CAD platform. Only a few small companies such as Autodesk and VersaCAD saw this opportunity and pursued it agressively. Already, in areas such as electronic schematic capture, designers were starting to use PC-based software with increasing frequency. Within a decade, Intergraph would end up switching once more – this time from the Clipper-based UNIX workstations to Windows and the PC.

Another issue which would later cause Intergraph untold grief was its focus on being a manufacturing company. By mid-1986 the company had grown to 5,100 employees and was one of the largest employers in northern Alabama. Over the next five years this number would double to over 10,000. Most of these employees staffed the company's growing manufacturing operation.

While the early VAX systems the company sold were virtually standard Digital products except for the File Processor and Graphics Processor, the Micro II systems were Digital's MicroVAXes repackaged by Intergraph. Not only did the company produce its own terminals as did many other turnkey vendors, but it was the only vendor that actually manufactured its own display monitors. The result was perhaps the best CAD display on the market but the cost was a huge manufacturing infrastructure.

The October 1986 issue of the *Computer Aided Design Report* contained a detailed analysis of Intergraph. In it Steve Wolf wrote:

> " We tried hard to dig up an Intergraph user who didn't like the product or the company. We didn't find one. Most reported that the company seems genuinely interested in making suggested improvements. They report that hardware reliability is excellent……Intergraph's software combined with the powerful Interact terminal is probably the best two-dimensional drafting system available at any price……The firm has built good products because it has a small closely knit team of hardware and software wizards lead by one man with a good sense of market timing. As it becomes larger, however, it's doubtful that Meadlock can continue to control Intergraph as easily as he has done in the past."[36]

### Intergraph starts serious run at mechanical CAD market

In the latter part of 1986 Intergraph began a major push into the mechanical market space with the launch of I/EMS (Intergraph Engineering Modeling System). The software combined an object-oriented database, NURBS as the means of defining all geometric entities except points and B-REP solids. While these technologies had all been around for several years, no one had combined them in a commercial system due to the computing resources required. With a 5 MIPS InterPro/32C, Intergraph had a platform

[36] *Computer Aided Design Report*, October 1986, Pg. 1

that could handle this software with barely adequate performance. Everyone knew, however, that more powerful workstations were just around the corner.[37]

A prototype of this software was shown at AUTOFACT '86 in Detroit in November 1986. The software was demonstrated running on an InterPro 32C workstation, not on a VAX using the InterPro 32C simply as a terminal. Steve Wolf, who typically was quite reserved when describing new CAD products was ecstatic about I/EMS.

> "Thanks to the computing speed of the Interpro 32C, interactive graphics run faster on this device than on any we've seen. The Interpro 32C is so fast that it lets designers mold sculptured surfaces interactively as if they were putty. Move a control point and the Interpro shows instantly the effect that the change will have on the surface…..Dazzling is the only word we can think of to describe the user controls of Intergraph's new applications."[38]

The version of I/EMS previewed at AUTOFACT supported dimension-driven mechanical drafting. The designer could define the relationships between geometry and when a dimension was changed, the geometry would adapt to that new value. While, this capability was not as comprehensive as what Parametric Technology would introduce a few years later, I/EMS did precede Pro/ENGINEER by several years.

The performance and functional capabilities incorporated into I/EMS were partially due to the fact that it was new software that used advanced concepts such as object-oriented programming. This enabled Intergraph to associate NC tool paths with model surfaces. If the surface was changed, the tool paths could be regenerated without additional user intervention. Wolf stated that tool paths that took 30 minutes to generate on a VAX system took only 30 seconds on the InterPro 32C. The software was scheduled to be released in mid-1987. Intergraph began shipping beta test versions of I/EMS in December 1986 and by May 1987 had installed about 100 copies.

**Intergraph becomes a workstation vendor**[39]

1987 was a year of transition for Intergraph and for the CAD/CAM industry in general. Other than CADAM, Inc. and a few others, vendors were rapidly switching away from minicomputer and mainframe-based systems to engineering workstations and to a lesser extent, personal computers. Customers were quickly becoming comfortable with the idea of purchasing industry-standard workstations running the UNIX operating system and linking them together in networks using the Ethernet protocol.

By this point, most major users of CAD technology were already on their second or third generation system and the sophistication of the users was increasing rapidly. To some extent, they were willing to purchase hardware and software separately even if it meant dealing with multiple vendors.

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[37] *Anderson Report*, May 1987, Pg. 1

[38] *Computer Aided Design Report,* December 1986, Pg. 5

[39] Most of this section is based on an extensive report on Intergraph in the June, 1987 issue of *The Anderson Report.*

There was another major trend impacting the vendors in this industry – the price of CAD technology on a per seat basis was falling like a rock. In four years the typical system had dropped from $90,000 per seat to about $40,000. Although the volume was increasing, it was not increasing fast enough to maintain the 30 to 50 percent overall industry growth rates of prior years. By 1987 annual growth had slowed to 12 to 15 percent. In the first quarter of 1987 Intergraph had revenue of $128 million compared to $147 million during the same period a year earlier. Each vendor reacted to these changes differently.

Some companies, such as SDRC were becoming pure software vendors while others such as Calma and Auto-trol resold workstations purchased from Sun and Apollo. Computervision acquired workstation components from Sun and added other hardware elements to the products it sold. The other choice was to become a workstation vendor and sell these systems to the general technical market as well as incorporate them into the CAD/CAM systems the company sold. With the InterPro/32C, Intergraph decided to follow this latter path.

There were a number of reasons why Intergraph became a workstation vendor. First, Digital was becoming more and more difficult to work with even though Intergraph was Digital's largest OEM customer. By mid-1987, the company had installed over 3,000 VAX systems with over 15,000 terminals. Digital was cutting OEM discounts and for a period of time treated details about its VAXBI bus as proprietary information. The latter step made it impossible for Intergraph to interface its communications and file processors to the latest VAX systems. Although the two companies eventually resolved this issue it probably convinced Intergraph managers that Digital was no longer a reliable partner.

Another major reason that Intergraph decided to build its own workstations and servers was that the company had built up a considerable manufacturing infrastructure in Huntsville. Most of these facilities were fairly new and shutting down this operation would have been very expensive. Also, manufacturing its own workstations was expected to generate more profit for the company as compared to reselling workstations from companies such as Sun or Apollo.

Since the company's software did not run on other UNIX workstations, if a customer wanted Intergraph software then it had to buy the workstations from Intergraph also. The extreme degree of vertical integration at Intergraph was demonstrated by the fact that the company had a fleet of ten tractor-trailers crisscrossing the United States and Canada delivering systems to its customers rather than relying on commercial carriers.

Intergraph's customers were enthusiastic about the new InterPro products with nearly 2,000 Clipper-based workstations on back order by mid-1987. The problem was that Fairchild was only delivering 75 to 100 C100 Clipper chips per week, about the same volume as incoming orders. Within a few months this shortage was corrected and Intergraph was able to clear its backlog.

A more significant problem was that Intergraph had decided to fundamentally rewrite its software for the new UNIX workstations rather than simply port the legacy VMS software to these machines. In the long run that was probably the right move but in the short run it led to there being little software that ran in native mode on the InterPro 32/C. There were perhaps a dozen packages available with another 15 scheduled by the end of 1987.

 

If the company was to be a viable workstation vendor, it needed more software for its customers to use. In February 1987 Intergraph had announced that it was entering the general purpose workstation market and it began soliciting third party software vendors to port their software to the InterPro 32C. There was a fatal flaw in this strategy, however. A large volume of workstation sales at Sun and Apollo came from CAD/CAM software vendors, either directly as OEM resellers or indirectly by referral. This was a major portion of the workstation market in the late1980s and none of these software companies were particularly interested in supporting a platform produced by a direct competitor when viable alternatives were available.

But Intergraph pushed ahead with its workstation strategy and in July 1987 introduced a family of new workstations that still used a 5 MIPS C100 Clipper microprocessor. Memory ranged from 8MB to 80MB and larger disk memories were available. A new GZ graphics accelerator capable of nearly real time generation of shaded images was available at the high end.

The GZ was the beginning of a long line of high-performance graphics accelerators that would eventually result in a separate business unit focused just on these devices. With these new workstations and servers Intergraph adopted more industry standards. Its Ethernet communications now supported TCP/IP as well as XNS, the company planned to begin using the X Windows graphics standard along with the MOTIF user interface and Intergraph also planned to support Sun's NFS file protocol.

The company stated that it would continue to market and support VAX systems, but the reality was that little new software was being developed for these platforms. Initially, the concept was that the VAX computers would be used to manage large project data files while the Clipper workstations would be used for interactive work. Most customers did not like the idea of supporting two hardware platforms and two operating systems and once Intergraph's servers were able to handle large volumes of data, this idea faded into the background.

The other problem facing Intergraph as it tried to build a commercial workstation and server business was that it was dependent upon Fairchild for progress in microprocessor performance and Fairchild was only marginally up to the challenge. In July 1987, Sun Microsystems introduced new workstations that used a 10 MIPS SPARC processor, twice the raw performance of Intergraph's then current Clipper systems.

**Taking control of its own microprocessor destiny**

Fairchild Semiconductor was owned by Schlumberger Ltd., the huge international oil field services firm. Schlumberger had acquired Fairchild in 1979 for $425 million. It turned out to be a major disappointment for its new owner and by mid-1987, Schlumberger was discussing sale of the subsidiary to National Semiconductor. National made no secret of its plans to shut down the Clipper microprocessor operation once it completed the acquisition.

Having selected and then dropped National's microprocessor product line, Intergraph was now faced with making another significant change in its product line. This time it was a much more serious situation since Intergraph had already sold more than 3,000 Clipper-based workstations and servers. An abrupt termination of the product line would have meant the loss of the Clipper development staff and no future processors even if National continued manufacturing the existing products for some period of time.

 

In September 1987, Intergraph signed an agreement with National to acquire the Advanced Processor Division of Fairchild to be effective when National completed its acquisition of the remainder of Fairchild. Intergraph announced its plans when it did in order to keep the Clipper development and manufacturing staff together. Schlumberger subsequently sold Fairchild to National for $122 million and at the same time Intergraph acquired the Advanced Processor Division for an estimated $10 million including all microprocessor designs and other intellectual property. As described below, the timing of Intergraph's acquisition and what was included as far as intellectual property would be the basis of several major lawsuits a decade later. But for now, Intergraph controlled its own destiny as far as the Clipper was concerned.

Within a few months Intergraph was ready to roll out a new C300 Clipper microprocessor at AUTOFACT '87 that was rated at 13 MIPS, almost three times the performance of the initial C100[40]. Internal floating point performance was rated at 3.0 MFLOPS. According to *The Anderson Report*, this was the level of performance needed to support new object-oriented applications such as I/EMS.[41]

The company also introduced the low-cost InterPro120 which used the older C100 processor. With 6MB of memory, a hardware floating-point accelerator, an 80MB disk and a 15-inch color monitor, this unit had a list price of just $16,000. A 19-inch monitor raised the price to $19,000. Typical of a new generation of customers was Embraer, the Brazilian manufacturer of small airliners, which purchased 135 InterPro workstations and software for $6.4 million.[42]

## Creating a new generation of software products

In mid-1986 the company's management structure still had Jim Meadlock as president and CEO with William Zarecor as executive vice president responsible for overall marketing activity. Bob Thurber was also an executive vice president, responsible for most AEC and mapping activity. Under Thurber, Dr. Eddie Boyle headed up AEC and Utilities while Larry Janzen was responsible for mapping and energy industries.[43] Boyle, with a civil engineering degree from Belfast's Queens University, was one of the first non-Americans to hold a senior position at Intergraph.

One of Intergraph's new software packages for its UNIX workstations was Master Architect, a model based design tool that used object-oriented software development techniques. Design elements could be linked together in an intelligent manner so that when a user moved a door or window, the walls were adjusted appropriately. The $10,000 package enabled users to work with three-dimensional views of the building model and two-dimensional drawings at the same time.

Gradually, the number of third-party software packages available on Intergraph workstations began to grow. At AUTOFACT in November 1987, four companies announced plans to port their software to Intergraph's Clipper workstations. These were

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[40] Most of the early C300-based workstations were rated at just 10 MIPS operating at 40-MHz. The 13 MIPS performance was probably for a 50-MHz processor which the company initially had problems producing.
[41] *The Anderson Report*, December 1987, Pg. 3
[42] *The Anderson Report*, December 1987, Pg. 7
[43] *A-E-C Automation Newsletter*, June/July 1986, Pg. 9

Moldflow (plastic flow prediction), Cincom (manufacturing information), SILMA (robotic simulation) and Engineering Mechanics Research (finite element modeling).

Intergraph's internal software development organization continued to churn out new software programs in 1988 including one of the first implementations of IGES 4.0, an enhanced Product Data Manager package and a new Intergraph/Network File Manager. The latter package provided check-in/check-out capabilities with the data stored on either a VAX or a Clipper system. The company also added new NC software to the I/EMS product line. Subsequent to the acquisition of Ana Tech described below, Intergraph introduced I/Image software which enabled a user to combine scanned raster data with vector data.

**New higher performance workstations and servers**

Intergraph announced a number of high performance workstations beginning with the InterPro 3070 at AUTOFACT '88 in Chicago. This workstation used a 40-MHz C300 processor rated at 10 MIPS and had a 27-inch monitor, the largest then sold commercially for CAD/CAM applications. The display processor supported two million pixels at 1664 by 1248 resolution. The 3070 was priced at $56,000. The company was thought to be working on a new version of the Clipper that would run at 60 MIPS.

The 3070 was followed in January 1989 by two C300 servers, the InterServe 3005 and the InterServe 4000. The latter machine supported up to 23GB of disk storage. This was followed by two new workstations, the 3050 and the 3060. A separate Intel 80386 processor supported input/output functions. Display resolution was 1184 by 884 and up to 512 colors could be displayed. In February, Intergraph announced a new higher performance microprocessor, the C300 Plus. Rated at 30 MIPS, it was initially offered in a server configuration, the InterServe 3505 with 32 to 160MB of memory and up to 6.5GB of disk storage.

In the spring of 1989, Intergraph broaden its market reach by introducing an Apple Macintosh version of MicroStation as an entry level design and drafting tool. The software was data compatible with VAX and UNIX versions of Intergraph's IGDS software. It handled three-dimensional models including producing shaded images. Up to 32 reference files were supported as were normal Apple functions such as the clipboard, a one-button mouse and Undo/Redo. The user interface supported over 450 commands.

One of the key features of MicroStation was that data files were binary compatible on all the platforms the software was offered on. Therefore, files could easily be exchanged between PC, VAX, Apple and Intergraph systems without a conversion step. Also, MicroStation operated on disk-based files rather than memory-based files meaning that if there was a power failure or system crash, valuable data would not be lost.

**Document scanning**

In August 1988 Intergraph acquired ANA Tech Corporation of Littleton, Colorado. ANA Tech was a manufacturer of large format scanners capable of handling engineering drawings and maps as well as a developer of software for editing and converting scanned raster images into vector data files that could be processed by computer graphics software such as Intergraph's IGDS.

 

ANA Tech had evolved from an earlier company, Interactive Systems Corporation. The key component for processing scanned drawings was a special processor called the VANA for **V**ector **ANA**lyzer as described below. A complete system consisted of:

- A large format document scanner,
- The VANA Vectorizer,
- The VANA Controller (VAX 11/750)
- And software for tying it all together.

In its early days, circa 1982, the company used scanners produced by companies such as Optronics and Systems Group. The latter company produced a scanner specifically for use with the ANA Tech system. The VANA Vectorizer was a custom designed array processor which converted scanned raster data to vectors as a document was being scanned. It was very fast – capable of processing an E-size drawing in several minutes.

The VANA Controller was a standard Digital VAX 11/750 computer with a Megatek 7210 graphics controller capable of supporting two monochromatic or color displays. The software was capable of symbol and character recognition using the vectorized data as its starting point. A complete VANA system including a System Group scanner and VAX computer cost $665,000.

The focus on vectorizing raster data was based on the fact that contemporary CAD systems were not capable of manipulating raster images. These system handled legacy documents using several different techniques. The most common approach was to tape the drawing to a large digitizer table and manually digitize the document line by line. A second approach was to scan the document, display the raster image on a CRT display and use specialized computer software to create a vector and character overlay of the scanned image. The third approach was to convert raster images to vector files either using software in the CAD system or a specialized system such as the Ana Tech VANA.

The key people behind ANA Tech were David Grover, president, Curtis Lipkie, vice president responsible for software development and Eugene Kleca, vice president responsible for hardware development.[44]

Meanwhile, Intergraph was developing its own expertise in the scanning area. Using scanner hardware from Optronics, a company it would later acquire, Intergraph offered a documents scanning product that included a hardware raster to vector conversion unit simply called the Graphics Processor. As with ANA Tech, character recognition was not particularly effective in the 1983 timeframe. Throughout the 1980s, ANA Tech struggled to become a viable company. There were several infusions of additional venture capital as well as management changes until Intergraph acquired the company in 1988. Gradually, the VANA Vectorizor was phased out and the company focused on large format scanners and raster processing software.

In June 1992 ANA Tech introduced the Eagle 4080ET scanner with 800 dpi resolution. It was priced at $35,000 and worked with PCs as well as Intergraph and Sun UNIX workstations. A color version, the Eagle 4080C was introduced in late 1993 priced at $95,000. It could scan a 41-inch wide multi-color map in 12 minutes and at the same time separate the data into seven layers based upon the colors on the original document.

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[44] *A-E-C Automation Newsletter*, August 1982, Pg. 8

When a USGS Quad sheet was scanned and then plotted on an HP inkjet plotter it was hard at first to tell the plotted copy from the original.[45]

A key product that came out of Intergraph's association with ANA Tech was the I/RAS software for editing raster data. I/RAS was tightly integrated with MicroStation. The software could be used to replace raster data with vector elements. New vector elements were overlaid on the raster image and then once the user was satisfied with the results, the raster data was removed. There were several different version of the I/RAS software.

In mid-1995, ANA Tech introduced a new low-cost scanner, the Eagle SLI 3840. This 100-pound desktop unit could scan an E-size drawings in as little as 15 seconds at 200 dpi resolution. It was capable of resolutions as fine as 800 dpi and sold for $12,800 in the United States.[46] ANA Tech began to increase its focus on raster editing software around 1996. In that year it introduced its SCANSMITH line of software designed for real-time scanning and post-processing of raster documents. This was followed the next year with the company's PREDITOR (Professional Raster Editor) software package that enabled user to edit large raster images irrespective of the scanning equipment being used.

In April 1998, Intergraph established a new Imaging Systems Division with Lewis Graham as its vice president and manager. This division consisted of the company's photogrametric and reprographics software, the ImageStation Z, PhotoScan TD precision scanners and the ANA Tech scanning hardware. With this change in management, Eugene Kleca and Curt Liepke, both ANA Tech founders, left Intergraph and set up a new company, Image Peak Systems.

### Intergraph at the end of the 1980s

During the 1980s, Intergraph grew rapidly, created a global presence, became a significant manufacturer of UNIX workstations and servers and added tens of thousands of users. It was clearly a company "on a roll." The November 1989 issue of *The Anderson Report* was optimistic about Intergraph's future:

> "In our view the company made the right decisions. Intergraph has done an excellent job of merging a UNIX-based product line with their VAX/VMS-based solutions….. rather than porting existing applications to UNIX, Intergraph made a decision to develop new object-oriented foundations for their CAD/CAM software. This choice held even higher risk than the decision to build workstations."

By the end of 1989, over 80 percent of the company's system revenue resulted from the sale of UNIX workstations and related software. The only reason it was not 100 percent was that there were still some applications such as plant design software that were only available on VAX systems. Not only was Intergraph attempting to develop a commercial business selling Clipper-based workstations and servers but its was also attempting to sell Clipper microprocessors to other computer system vendors. In the end, it was successful in doing neither. One area where it was starting to have an impact,

[45] *Engineering Automation Report*, December 1993, Pg. 3
[46] *A-E-C Automation Newsletter*, June 1995, Pg.12

 

however, was in the PC CAD market. MicroStation was available on IBM-compatible PCs and Apple Macintosh machines as well as Intergraph's own UNIX workstations.

The biggest inhibitor to selling commercial Clipper-based systems was the lack of third party software. Intergraph claimed that there were 500 programs available for these systems, half from independent software firms. The reality was that few of these software companies treated the Clipper systems as a primary platform and many of these packages handled minor applications with limited customer demand. There simply were few main-stream software packages available that could stimulate hardware sales other than Intergraph's own software.Towards the end of 1989 Intergraph introduced several 50-MHz C300 workstations, the 3280 and 3285, which ran at 14 MIPS, the speed originally expected for this microprocessor when it was first introduced. As the year came to a close, Intergraph had an installed base of perhaps 26,000 Clipper systems.[47]

Intergraph had an extremely broad set of its own software products at this point in time, but some cracks were beginning to show. For example, I/EMS which had been introduced in 1986 was only in its second major release three years later. Competitive products such as PTC's Pro/ENGINEER had not only caught up with I/EMS but had surpassed it in functionality. In the mapping and AEC areas, Intergraph was clearly the industry leader with a growing number of applications running on the company's Clipper workstations. New packages such as InRoads for highway design and InFlow for hydraulic design were becoming well accepted industry standards. One weak area was in electronic design where the company offered a rather straight-forward set of packages for the physical design of circuit boards and hybrid circuits.

The end of 1989 also marked a significant management change at Intergraph. The company acquired Quintus Computer Systems, a developer of Prolog-based[48] software development tools. The president and CEO of Quintus was Elliot James who subsequently became president of Intergraph. Jim Meadlock retained his chairmanship of the company's board and his position as CEO. There never was any question as to who was really in charge, however. Although he was supposedly semi-retired and was spending more time at his vacation home in Jupiter, Florida, Meadlock's influence continued to be felt throughout the company.

Overall, as the company got ready to enter the 1990s, it was functioning as a well oiled machine. It had excellent hardware products that covered all the typical user's needs except for plotters and these were readily available from companies such as Hewlett-Packard and CalComp. Its software dominated the high-end mapping and AEC markets and it had adequate mechanical software. The company was profitable and had fairly good management depth. The problem was what over the horizon – the shift to PCs and an entirely different economic model for CAD vendors – changes that would see Intergraph stumble, make some hard decisions and eventually emerge as a well financed software company focused on specific market sectors.

### Trying to offer something for everyone

One significant characteristic of Intergraph's product strategy in the early 1990s was an attempt to be all things to all people. The company began to aggressively market

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[47] *The Anderson Report*, December 1989, Pg. 4

[48] Prolog is a programming language used to develop logic oriented software packages sometimes referred to as "artificial intelligence."

its Clipper workstations and servers as industry standard products, taking specific aim at Sun Microsystems. Ads appeared in a wide range of publications claiming feature by feature that Intergraph's systems did everything that Sun's products did. Intergraph pushed hard to increase the number of third party software packages available on these systems. The company's attempt to market the Clipper microprocessors to other computer manufacturers, however, was suspended in October 1990.

By late 1990, the company was claiming the availability of 900 software packages on the Clipper platform, 600 of which came from other companies. In spite of this momentum, industry observers as well as users were questioning the long term viability of proprietary processor technology. Shortly after Intergraph committed to porting MicroStation and I/EMS to Sun Microsystems workstations as described earlier, *CAD/CIM Alert* commented on the Clipper product line:

> "However, we wonder how long these platforms can last. Even though there is a large installed base of customers, the days when proprietary hardware platforms ruled the roost are long since gone."[49]

Intergraph continued to expand the Clipper product line, however. At AUTOFACT '91 in Chicago, the company launched the two chip C400 Clipper processor. Running at 40 MHz, it was rated at 33 SPECmarks, 33 MIPS and 9 MFLOPS. This was faster than anything Sun Microsystems then had on the market and the expectation was that Intergraph could crank the speed up to 100 MHz in the future. The new 6400 workstation product line using this processor started at $24,900 for the Model 6450. The 6480 with 24-bit graphics was priced at $37,900[50] Around the same time, Intergraph announced that it would no longer offer Digital systems.

Intergraph's revenues reached a high water mark of $1.2 billion in 1991 although earnings were no higher than they were in 1987. The company's stock price in mid-1992 was $17 per share, about what it had been nearly a decade earlier and half what it was in mid-1991.[51] The commoditization of the CAD industry was becoming increasing clear. Maurice Romaine, one of the company's multiple executive vice presidents, stated: "The question is how we will be able to deliver lower and lower cost hardware seats and still provide the level of complete package solutions and value-added services." This is an issue that would plague the company for the next decade. About this time the company's employment peaked at somewhat over 10,000.

Additional C400 workstations were introduced throughout 1992 while prices on older C300 units decreased substantially. In early 1992 the C300-based InterPro 2020 with 16MB of memory, a 486MB disk and 19-inch color monitor was reduced from $16,900 to $12,500. A similarly configured C400-based 2430 was priced at $18,500. While Intergraph was moving fast to improve the price/performance of its workstations, the competition was moving even faster. Hewlett-Packard's Model 705 offered about the same performance as the 2430 but at the price of a 2020. Intergraph kept pushing and an 80 MHz C400 processor was launched in early 1993 along with a new batch of workstations. Some of these sported a two-megapixel 21-inch color monitor.

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[49] *CAD/CIM Alert*, March 1991, Pg. 12
[50] *The Anderson Report*, December 1991, Pg. 3
[51] *Engineering Automation Report*, June 1992, Pg. 6

 

Well into 1992 Intergraph's management was adamant, at least to outside observers, that building their own workstations with their own microprocessors was the right way to go. At that point in time there was no clear winner among the many RISC processors on the market and companies such as Sun, Digital and Hewlett-Packard had already switched directions several times. Intergraph justified development costs by stating that at $12 million annually, the Clipper represented less than 10 percent of the company's total R&D budget.

Spread over 17,000 computer systems per year, this was a little more than $700 per unit. Since they did not have to pay another company for these systems, they felt they were able to maintain competitive prices. In addition, by building all the components, Intergraph was able to fine tune them to work effectively together. Although the latter was a valid point, economics would soon force Intergraph to change directions.

While Intergraph was focusing much of the company's energy on the hardware side of the business, it was also pouring considerable resources into software development as described below. This was the most comprehensive set of application programs offered by any one vendor.

**MicroStation –** Although the Clipper and PC versions of this software took top priority, work progressed on porting MicroStation to other UNIX platforms. A Sun version of MicroStation Version 4.0 began shipping in early 1992. While Intergraph was a proponent of the industry-standard MOTIF user interface, Sun was pushing its own OPEN LOOK interface. Intergraph and its Bentley partner compromised and provided both interfaces and left it up to the user to select which would be utilized.

Early versions of this software did not fully take advantage of the graphics hardware in the Sun workstations resulting in mediocre performance compared to Intergraph's InterPro and InterAct workstations. Interestingly, if the Sun workstation was equipped with dual monitors, the software would support them much like the way MicroStation ran on a dual screen Intergraph workstation.[52] Support for Hewlett-Packard workstations followed in mid-1992. MicroStation was competitively priced against AutoCAD at $3,450.

**AEC Applications –** Intergraph offered as broad a suite of architectural and civil engineering applications as any vendor. These covered everything from electrical to HVAC to surveying to roadway design. Most worked fairly well with each other. This particular market was rapidly shifting from UNIX workstations to PCs and the company's dealers were taking on more of the sales and support responsibility for these customers.

**Plant Design System –** The PDS software developed working with Zydex Engineering was rapidly becoming a key part of Intergraph's business. While the AEC software tended to be sold to small firms except in the highway design sector, PDS was still a workstation oriented market and the customers were large engineering firms and owner/operators. The primary competition was PDMS developed by the UK's Cadcentre. Several visualization packages were available to support PDS and AEC applications. ModelView provided a variety of color selection and texture definitions as well as several alternative ways of generating images including ray tracing. DesignReview extending this capability to include navigation through complex three-dimensional models.

[52] *Engineering Automation Report*, April 1992, Pg. 4

**Mapping –** The company's mapping software had been rebuilt during the prior several years and reintroduced as the Modular GIS Environment (MGE). It was much more database oriented than earlier software and supported Oracle, Informix and Ingress database management systems. The major focus was in producing maps for government agencies as well as for organizations engaged in oil and gas exploration. The company's primary competitor was ESRI which was more focused on thematic mapping.

**Facility Information Management –** A growing portion of Intergraph's business was selling mapping system to electrical, gas and telephone utilities. Automated Mapping/Facility Management (AM/FM) software was a combination of mapping, database management and specialized applications. Intergraph called its newest product in this area FRAMME (Facilities Rulebase and Application Model Management Environment). Intergraph was particularly proud of utilities that had computerized 100 percent of their maps. They called this the 100% Club. In mid-1992, there were 15 members of the "club".

**Dispatch Management –** Intergraph took its mapping software and graphics visualization capabilities and added some specialized software to meet the needs of emergency dispatch centers. This was a good case of extending existing technology into a new market. Eventually, this would become a major component of Intergraph's business, but not without some growing pains.

**Mechanical –** Intergraph began putting more resources in developing mechanical design and manufacturing software in the late 1980s. I/EMS Release 1.3 came out in early 1990 with dynamic dimensioning, interference checking, a customizable user interface and other productivity enhancements. This was followed later in 1990 by I/Punch for water-jet and laser cutting machines, I/Fold for sheet metal design and I/Design for conceptual modeling.

Several additional releases followed in short order. Intergraph offered its own analysis software as well as Applied Structure licensed from Rasna Corporation and sold as I/Rasna. In March 1993, Intergraph dropped the entry level price for I/EMS from $20,000 to $9,900 when it began selling a version with just basic design and modeling capabilities called EMS Foundation. Other bundles of EMS modules sold for $17,000 to as much as $25,900.

**Electronics –** By mid-1992, Intergraph Dazix subsidiary was selling a fairly complete suite of software for the design of integrated circuits, printed circuit boards and multichip modules.[53]

## Intergraph and the Federal Government

No discussion about Intergraph would be complete without a detailed review of the company's relationship with the federal government. Over the years this activity had three primary components: custom programming projects, many of which involved classified work; the sale of standard Intergraph hardware and software products; and large competitively bid contracts particularly with the U.S. Army Corps of Engineers and the U.S. Navy.

Intergraph sold several VAX-based systems to various Corps of Engineers offices prior to 1986. In 1986 the Corps issued a Request for Proposal (RFP) for about 20 CAD systems that would be installed its design offices around the country. In addition to

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[53] *Engineering Automation Report*, June 1992, Pg. 6

Intergraph, serious bidders included Auto-trol Technology[54] and McAuto. Intergraph won this contract eventually worth over $80 million.

The Navy's CAD-2 program was much larger than any CAD procurement previously or since. In 1981 the Navy awarded Computervision a large contract for systems to be used for both mechanical and AEC applications. Known as CAEDOS for Computer-Aided Engineering and Documentation System, it was the first in the CAD industry for what was known within procurement circles as an "indefinite quantity, indefinite delivery" contract. What this meant was that the government awarded a contract to the winning bidder without any guarantee that it would procure the full amount of product covered by the contract although there was typically a minimum quantity defined. A maximum quantity for each line item was also defined in the contract.

Sometimes these contracts were a goldmine for the vendor and sometimes they were a disaster. CAEDOS was a goldmine for Computervision. The contract, which was actually awarded by the Naval Weapons Center at China Lake, CA, called for a minimum of 135 workstations and a maximum of 405. By 1985, the Navy had purchased the maximum number of workstations allowed and Computervision had received orders for $99.9 million of hardware, software and maintenance services. As of December 1985, the Navy expected to have a new contract for next generation CAD systems in place by 1987. That did not happen and Computervision probably booked millions in additional revenue from the Navy with small sole source deals for additional systems and workstations as well as maintenance over the next six years.

An extensive CAD-2 briefing was given by Dale Christensen in Washington in December 1985 at the Defense Computer Graphics Conference. Christensen had been involved in the earlier Computervision contract and was instrumental in the establishment in 1980 of the National Computer Graphics Association (NCGA). The formal launch of the CAD-2 procurement occurred with a pre-solicitation conference at the Naval Surface Weapons Center in White Oak, MD on February 7, 1986 in the midst of a fairly heavy snowstorm. At this time, the Navy issued a preliminary Request For Information (RFI).

CAD-2 (that name actually came into use somewhat later) was intended to be the middle stage of a three stage process. CAEDOS, which automated discrete processes, was considered stage one. CAD-2, the second acquisition, would cover the period from 1987 to 1991 and would extend the automation of these discrete processes. In 1993, the Navy planned a third procurement which would link together multiple automated processes. It sounded good. The problem was that the Navy proved incapable of executing the CAD-2 procurement in a timely manner and the technology kept changing faster than the Navy could keep its specifications updated.

The initial plans for the CAD-2 procurement took the form of a matrix of functional requirements. Five different technical areas were identified: design, engineering analysis, manufacturing, drafting and technical publishing. There were four processes identified by the Navy: naval architecture, mechanical, electronic and AEC. Except for the fact that ship design and AEC had no manufacturing requirements, each process had needs in each technical area. A July 1986 amendment to the RFI added an additional area, aircraft design, to the initial draft specifications.

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[54] I was the head of Auto-trol's Government Systems group at the time and directly responsible for the company's bid to the Corps of Engineers

 

In 1986 the plan was to award multiple contracts for commercially available hardware and software. These would be indefinite quantity, indefinite delivery contracts from which Navy organizations would order what they needed. Although the Navy kept stating that CAD-2 would be a large program, no dollar figures were provided by government personnel. One number did catch everyone's attention. That was the fact that there were over 40,000 civilian and military technical professionals in the Navy. This was the time when the federal government under President Reagan was working towards a 600-ship Navy. The media started talking about this procurement as a $500 million to $1 billion program.

Most vendors expected a formal RFP before the end of 1986. Instead, the Navy scheduled a series of meetings with potential bidders for the purpose of discussing the specifications. It wanted industry input on what was considered beyond current vendor capabilities as well as what had been left out. These meetings took place at the Naval Weapons Center, China Lake, CA. Over 50 companies made the trek to this facility in the middle of the Mohave Desert to spend a few hours discussing the preliminary specifications with Navy personnel who had been drawn together from a wide range of Naval organizations.

At China Lake, Christensen stated that the RFP would be out sometime between February and April, 1987, but it quickly became apparent that this was not to be. Instead, the Navy issued a second Request For Information in early January 1987. With this second RFI, the Navy made several major conceptual changes. Most significant was that instead of focusing on discrete engineering disciplines, the procurement was being restructured into five specific command-centric procurements:

- Ships - Naval Sea Systems Command (NAVSEA)
- Airplanes – Naval Air Systems Command (NAVAIR)
- Buildings – Naval Facilities Engineering Command (NAVFAC)
- Electronics – Space and Naval Warfare Systems Command (SPAWAR)
- Printing – Naval Supply Systems Command (NAVSUP)

There was a growing recognition within the Navy that each of these areas had unique requirements. The new plan was to have a common core of requirements for computer and communications equipment, operating systems, office software and basic CAD capabilities with mission specific software for each command. In January 1987, the Navy asked vendors for a quick response to the second RFI so that RFPs could be issued. One problem was that the Navy planned to issue a single consolidated RFP document with each requirement identified as to its applicability to specific solicitations.

In early 1988 responsibility for CAD-2 was transferred from the Navy Sea Systems Command to the Naval Data Automation Command. At this point, numbers as large as $2.5 billion for the acquisition were being kicked around.

The General Accounting Office had initiated an analysis of the program in early 1987 based upon a request from the House Appropriations Committee. Its initial report, *Issues Concerning Technical Specifications for Navy's CAD/CAM Acquisition*, which was issued in March 1988, basically agreed with most vendors that the specifications were excessively detailed and would result in greater than necessary cost.

A second GSA report released in May 1988, *Navy CAD/CAM Acquisition Has Merit but Management Improvements Needed*, claimed that the Navy had not followed Department of Defense procurement regulations. Specifically, the report stated that

“Regulations require that user needs be established and validated, alternative solutions be evaluated, and a management plan for guiding an acquisition be developed, respectively, before a system solution is defined in a technical specification.” This report recommended that the Navy postpone release of CAD-2 RFPs.

Throughout the entire procurement process, the Navy was adamant that this was a UNIX workstation procurement and that PCs did not have the horsepower to satisfy its needs. In June 1988, the Navy was struggling with its budget for computer equipment and concern was growing as to where the money would come from for CAD-2. In one step to conserve funds, the Navy limited any CAD purchases to $50,000 until CAD-2 was awarded.

What this did was to create an opportunity for local AutoCAD dealers to begin selling PC systems to the Navy as “interim” solutions. The Trojan Horse was inside the gates of the fortress. Eventually, the Navy narrowed the procurement to three RFPs, one each for NAVSEA, NAVFAC and NAVAIR. These were released in 1999 and 2000.

Intergraph was awarded the first of the Navy’s CAD-2 contracts, a $362 million 12-year NAVSEA deal, in April 1991. The major competitor was Planning Research Corporation which was the prime contractor for Computervision’s bid. When the award was first announced in March, PRC filed a protest but this was soon dropped and the contract with Intergraph was finalized shortly thereafter.

The NAVSEA contract involved I/EMS software and Clipper-based workstations and servers. Although the Navy’s specifications called for industry standard computers, particularly the use of the UNIX operating system, they did not rule out proprietary components such as Clipper microprocessors. Within the first three years, Intergraph delivered $115 million of hardware, software and services to the Navy based on this contract.

The second of the Navy CAD-2 contracts to be awarded was the one for the Navy Facilities Command. Commonly called NAVFAC, this contract for 4,200 workstations and over 1,000 servers was initially awarded to Intergraph in September 1992 but was protested by Federal Computer Corporation (FCC) and Cordant Incorporated, a system integrator based in Reston, Virginia (originally called Centel Federal Systems).

The protest was based on the claim that the Navy’s benchmark had favored Intergraph. The GSA Board of Contract Appeals instructed the Navy to either award the contract to the low bidder, in this case FCC, or go through a new round of bidding with the benchmark evaluation criteria better defined.

After a year-long legal struggle and a new round of bidding, the Navy negotiated a deal to split the contract, estimated to be worth $550 million, between Intergraph and Cordant. The latter company offered a solution based on Autodesk’s AutoCAD software running on Sun Microsystems workstations. Intergraph’s proposal envisioned a combination of Clipper workstations and Windows NT systems. FCC, the original protester, eventually decided not to participate in the rebid of the contract. In typical government procurement practices, only $1 million in actual purchases was guaranteed to each vendor. This was quickly passed for both vendors within the first 30 days of the contract award.[55]

[55] I was a member of an advisory board established by the Navy to help guide it through the implementation of these systems.

The NAVFAC contracts included the ability for other federal government agencies to buy hardware and software products from Intergraph and Cordant. This enabled the Army Corps of Engineers to upgrade the VAX systems it had procured from Intergraph in the late 1980s with higher performance and lower cost UNIX and PC systems. Federal government civilian agencies such as the Department of State and the Department of Energy were also able to buy off the contracts up to a maximum of $50 million of hardware and software.[56]

Over the next four years, the Corps of Engineers, the Navy and other government agencies procured almost $250 million of CAD-2 hardware, software and services off the two NAVFAC contracts, about evenly split between the two vendors. The Army tended to purchase Intergraph products while the Navy tended towards AutoCAD. Most systems installed were PCs running Windows NT.[57]

The third piece of CAD-2, the NAVAIR/SPAWAR contract, was awarded to Intergraph in July 1994. Like the other contracts, it was also protested, this time by Grumman Aircraft. The GSA held up the award for a few months but it was finalized in November. This contract was for 3,600 workstations and 1,000 servers and included both mechanical and electronic design software. Worth $398 million, it provided Intergraph with the opportunity to sell a total of over $1 billion of hardware, software and services to the DOD over a period of nearly 15 years from when the first NAVSEA contract was awarded.

One interesting aspect of this latter contract was that the Navy's benchmark test was done nearly 18 months prior to the contract award. At the time Intergraph was proposing its 6400 series Clipper workstations. Since that product line had been discontinued by the time the contract was awarded, the Navy was able to switch many seats to newer PCs running Windows NT at a considerable savings in unit costs. This final CAD-2 contract was awarded nearly nine years after the Navy initiated plans for upgrading its engineering design infrastructure.

Intergraph's relationship with the Navy became complicated when Intergraph sold its mechanical business unit, including both I/EMS and Solid Edge, to Unigraphics Solutions in early 1998 as described below. I/EMS only ran on Intergraph's Clipper workstations and UGS had no interest in continuing the development of this now obsolete package. Also, the Navy was seriously switching away from UNIX and towards Windows NT PCs as its standard platform. In mid-1999, UGS and Intergraph got the Navy to agree to replace I/EMS with the Windows NT version of Unigraphics over a period of time.

**The game gets tougher**

Working with Bentley Systems, Intergraph launched MicroStation PC 4.0 in the fourth quarter of 1990. It included a new user programming language, MicroStation Development Language (MDL), which enabled users to embed C code in their customized MicroStation applications. This proved to be a key development and for well over a decade Bentley would use MDL as a primary application development toolkit. Around this time, Intergraph starting developing a dealer organization to sell the PC version of MicroStation and related PC applications. The company's direct sales force

[56] *A-E-C Automation Newsletter*, April 1994, Pg. 10
[57] *A-E-C Automation Newsletter*, July 1997, Pg.10

was the exclusive distribution channel for MicroStation on Intergraph's own Clipper workstations.

In 1992, Intergraph finally seemed to recognize Autodesk for the competition that company presented to traditional turnkey vendors. One competitive move was to offer a copy of MicroStation for $500 for each copy of AutoCAD turned in.

As the PC picked up steam in the CAD market, Intergraph started to take it more and more seriously. In November 1992 at AUTOFACT '92 the company announced that MicroStation 5, due out in 1993, would be available as a Windows NT application. In addition, the company announced that its broad range of MicroStation-based applications would also be ported to Windows NT to run on both PCs and the company's own Clipper workstations which would soon support NT as well as the company's own version of UNIX, usually referred to as CLIX. At the same time, Intergraph stated that it planned to continue manufacturing its own UNIX workstations. According to Tommy Steele who had recently joined Intergraph after a long career at IBM, "…our users will have a choice of operating environments: UNIX or NT. Intergraph will ensure seamless interoperability for mixed OS environments."[58]

As 1993 started, it looked as if Intergraph was in for a rough time making the transition to Windows NT while maintaining all of its existing UNIX products. In fact *Engineering Automation Report* said, "1993 is a year Intergraph might wish it could just skip. It is becoming harder for them to produce workstations that match the computational performance that other vendors bring to the table."[59] Early 1993 saw the introduction of a number of new workstations and servers based on the C400 processors. Although the company would introduce additional C400 systems in the future this was the last major Clipper introduction by the company.

For the most part, these units were price competitively with what the competition was offering. Intergraph had an advantage over its hardware competitors in that it offered 19-inch, 21-inch and 27-inch monitors, some of which it manufactured itself while other vendors did not offer the larger displays. The major issue the company was facing was the fact that its customers were increasingly interested in standardizing on a single computer manufacturer. If a company bought Hewlett-Packard workstations and MicroStation and later decided it wanted to switch to Pro/ENGINEER it could do so. This flexibility did not exist if the company purchased Intergraph proprietary machines.[60]

March 1993 saw a series of management changes at Intergraph. Elliott James who had been the president for the previous three years left the company and Jim Meadlock returned from semi-retirement to take over the reins once again. Lew Epstein, vice president of sales also left as did Warren Winterbottom who had been building the company's MicroStation dealer network. Doug Gerull, executive vice president for the company's mapping business was an additional casualty of the reorganization. Winterbottom eventually joined Bentley to head its sales operation as it prepared to go its separate way from Intergraph as discussed below.

The pending product transition was starting to have an impact on the company's financial results. In the first quarter of 1993 Intergraph eked out a small 2 percent gain in revenue to $282 million but showed a loss of $7.7 million. Foreshadowing future

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[58] *A-E-C Automation Newsletter*, December 1992, Pg. 18
[59] *Engineering Automation Report*, January 1993, Pg. 3
[60] *Engineering Automation Report*, February 1993, Pg. 5

 

problems was a drop in orders to $140 million from $184 million during the same quarter a year earlier. At this point in time the company's business was approximately one third software ( 20 percent of which was MicroStation) and two thirds hardware. The second quarter wasn't any better with revenue down to $249 million and a loss of $18.6 million.

At A/E/C SYSTEMS '93 in June 1993 in Anaheim, California, Intergraph showed off the new MicroStation Version 5 it expected to release later that year as well as several new architectural and civil engineering applications that were a result of its acquisition of a small Huntsville software company called AEC Group the prior year. When asked about plans for a new C500 processor, company executives were very evasive.[61] In fact, by the summer of 1993 it was clear that the C500 would not happen. On July 7, 1993, Intergraph announced that it had agreed to work with Sun Microsystems in the development of a new 64-bit SPARC microprocessor known as the UltraSPARC.

As part of this new strategy, Intergraph's Clipper design team was being integrated into Sun's design organization. The plan at the time also envisioned Intergraph implementing Windows NT on the SPARC platform although Sun made it clear that this would not be a Sun product. Intergraph already had a version of Windows NT running on the Clipper platform which it demonstrated at Windows World '93 in May 1993. At the time the joint effort with Sun was announced, the expectation was that the UltraSPARC would not be available until 1995. If Intergraph was simply looking for a replacement to the Clipper, it is surprising that the company did not select a readily available alternative such as DEC's Alpha or the R4400 from MIPS. Intergraph's response was that there were business issues to consider and they liked Sun's long term product strategy.[62]

Intergraph delivered on its MicroStation NT commitment in August 1993 along with a number of architectural, engineering and GIS applications. A combined hardware and software system called the PC 433 was launched at an attractive $6,500 price. It consisted of a 33 MHz Intel 486 processor, 16MB of memory, a 17-inch color monitor and MicroStation software.

Indicative of the shift to the PC was a new entry-level GIS system called MGE DOS SOLUTIONStation bundle. It consisted of Intergraph's Modular GIS Environment PC Product (MGEPC-1), MapInfo for Windows 2.1 and an Intergraph Technical Desktop-1 (TD-1), all for just $11,999. The TD-1 was a 66-Mhz Intel 486-DX-based PC with 16MB of memory, a 248MB hard disk and a 17-inch monitor.

MicroStation Version 5 began shipping in late 1993 for Windows, DOS (there was still a large number of user who liked the way DOS provided close control over computer operations), and Windows NT. One key capability of Version 5 was its ability to read and write AutoCAD .dwg files. Interoperability with AutoCAD would be a hallmark of MicroStation from this point forward. Availability of Version 5 on UNIX platforms including Intergraph-built hardware was scheduled for the first half of 1994.

Meanwhile, the company continued to pour money into its mechanical software activity which was headed by vice president Bill McClure. I/EMS Release 3 was introduced at AUTOFACT '93 with a variational and parametric design tool called SmartSketch. It utilized a smart cursor that allowed users to quickly grasp relationships and constraints.

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[61] *Engineering Automation Report*, July 1993, Pg. 11
[62] *Engineering Automation Report*, August 1993, Pg. 5

By early 1994 the company was doing approximately $200 million annually in the mechanical area although more than half was hardware and MicroStation made up a substantial percentage of the software portion. To support MicroStation as a two-dimensional mechanical design and ANSI-standard drafting tool, Intergraph licensed a $500 package called MicroDraftsman from HLB Technologies of Blue Ridge, Virginia. A separate package, Mechanical MicroStation which supported ISO and DIN drafting standards was sold in Europe.

Intergraph's marketing theme for its mechanical software was "art to part" or the ability to do everything from creative styling to detailed product engineering and documentation to manufacturing. One package that received little media attention was I/Design, an EMS option that provided functionality and a user interface that was more receptive to the needs of industrial designers than simply design engineers. Visualization was provided by the company's ModelView software.

It is hard to say why Intergraph was not more successful in the mechanical market. A number of factors influenced what happened: the lack of aggressive marketing, a sales force focused on the company's mainstream AEC and mapping products, mechanical software that was very broad in scope but not as functionally complete as the competition and simply insufficient corporate focus on this market. [63]

I/EMS was available on Sun and SGI workstations[64] as well as on the company's own Clipper workstations but there was no indication that the software would be ported to PCs nor did the company follow through with its plans to port I/EMS to Hewlett-Packard workstations. While Intergraph was moving the majority of its software product line to the Windows NT platform, the exception was I/EMS which remained a UNIX application. The lack of interest in NT regarding I/EMS was primarily because the company had an entirely new mechanical product under development – Solid Edge.

Intergraph's hardware concentration continued to shift towards PCs. In the spring of 1994 the company launched the TD-2 (Technical Desktop-2) which incorporated Intel's Pentium microprocessor and Microsoft's Windows NT operating system. With a 66-Mhz processor, 16MB of main memory, a 540MB disk, a Weitek P9000 video board and a 17-inch monitor, the TD-2 sold for $4,875. It was quickly added to Intergraph's NAVFAC contract described above.

**The Bentley/Intergraph relationship changes**

In retrospect, 1993 was the year that it became obvious that Intergraph's business model was fundamentally flawed. During that year's fourth quarter the company's sales were down 12.5 percent to $269 million and the company showed a $70 loss after taking a $76 million charge that resulted from closing manufacturing and distribution facilities in Europe.[65]

The May 1994 International Graphics User Group (IGUG) meeting in Huntsville marked a further significant shift in hardware strategy and a major change in the relationship between Intergraph and Bentley. Meadlock announced that while Intergraph

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[63] *Engineering Automation Report*, January 1994, Pg. 6

[64] Control Data Corporation had an agreement with Intergraph to resell I/EMS on SGI workstations along with additional CDC software. It does not appear that this ever resulted in significant revenue for Intergraph.

[65] *Engineering Automation Report*, February 1994, Pg. 14

 

would continue to resell MicroStation software, it would no longer be the exclusive channel for Bentley products effective January 1, 1995. See Chapter 10 for additional discussion concerning the split between the two companies.

In a presentation worthy of COMDEX, Jim Meadlock announced that Intergraph's future was with computer systems powered by Intel microprocessors and Microsoft operating systems, specifically Windows NT. He was joined on the podium by David House, a key Intel vice president and Mike Maples, the executive vice president of Microsoft. The company went all out to present itself as a "big league" player in the computer industry. Tommy Steele commented that: "Intergraph is the largest NT development site outside of Microsoft."[66]

Only eight years earlier, Intergraph had announced that the future was UNIX and the Clipper workstation. Now customers had to prepare for another substantial platform shift. To some extent, the company was forced into making this announcement. It had gone through a string of five profitless quarters and it was becoming increasingly clear that the Clipper was costing far to much in both R&D and production while the company was having problems keeping up with the competition from a performance point of view.

During the prior months talk about porting Windows NT to the Clipper platform had dried up and the agreement with SUN to jointly develop a 64-bit UnltraSPARC processor that would run NT never seemed to get off the ground. The Intergraph employees who had been working with Sun had quietly become Sun employees. Supposedly, Intergraph was still working on porting NT to the Sun platform but was doing so under contract rather than as a joint venture.

In typical Meadlock fashion, he saw that within a few years Windows NT and its derivatives would replace UNIX as the preferred operating system for engineering applications. As usual, he was not only right, but was also a few years ahead of most competitors. The company's intent was to use standard Intel microprocessors and add Intergraph's own graphics accelerators and monitors. The resulting units would be somewhere between PCs and workstations in performance and, as a result, Intergraph decided it would call them "personal workstations." By building its own product line of PCs and servers, Intergraph hoped to keep as much of its manufacturing infrastructure as busy as possible. Part of the announcement included three new PCs based on Intel's 90-Mhz Pentium processor called the TD-3, TD-4 and TD-5.

Intergraph's personal workstations were typically priced higher than standard PCs but less than UNIX workstations. While a TD-2 started at around $6,000, a TD-5 with dual 27-inch monitors and the high performance GLI graphics accelerator would set a customer back nearly $58,000. The company set out to sell these units to a much broader market than simply to their own CAD and mapping customers. As part of the company's strategy in establishing itself as a PC vendor, Intergraph had a separate booth at the A/E/C SYSTEMS'94 conference in Washington, D.C. just for its hardware products and had its computers in other vendors booths as well. It was strange to see AutoCAD running on an Intergraph computer system in the Xerox booth.[67]

Although the transition to personal workstations was rather straightforward for most of Intergraph's software, it caused substantial problems for the company's mechanical organization. In late 1994 the company was still talking about porting I/EMS

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[66] *The Anderson Report*, May 1994, Pg. 5

[67] *Engineering Automation Report*, July 1994, Pg. 8

 

to Windows NT but in the interim, Intergraph decided to offer Sun Microsystems' Solaris version of UNIX on its TD systems. This enabled Intergraph to offer I/EMS including a new I/EMS Lite version, on these computers. It was a cobbled together solution that did not excite many customers. I/EMS Lite was a stripped down version of EMS that sold for $7,900. It included SmartSketch, feature-based solids with dimension-driven revisions, drafting and integration with analysis and manufacturing applications. At the same time, Intergraph reduced the price of EMS Foundation to $4,900 and EMS Cornerstone, which was the most commonly purchased bundle of modules from $17,900 to $14,900.

In early 1995, the personal workstation nomenclature was changed. The TD-3 became the TD-30 and so forth and the multi-processor versions of these systems were relabeled TDZ-30, TDZ-40 and TDZ-60. These latter units utilized Intel's 100-MHz Pentium processors and supported up to six processors in the case of the TDZ-60. The TDZ-60 came with 128MB of memory expandable to 1GB.

By mid-1995, Intergraph had restructured the company five business units, each with profit and loss responsibilities. These were Software Solutions, Computer Systems, Federal Systems, Electronics (Dazix) and Public Safety, the latter a relatively new activity targeted towards selling mapping systems used for emergency dispatch. By the end of 1994, 85 percent of the computer systems the company was shipping were Intel-based PCs and servers. Most were being sold for use with Intergraph software with relatively few being purchased for general engineering and graphics applications. According to *Engineering Automation Report*: "Most potential customers, however, still seem reluctant to pay a premium for the Intergraph systems as compared to plain vanilla PCs."[68]

In late 1995, Intergraph introduced personal workstations that incorporated Intel's new 150-MHz and 200-MHz Pentium Pro processors. They used Intergraph-built motherboards, error correcting memory and the company's high-performance graphics cards. In general, they were a match for most RISC-based mid-range workstations.[69]

**A new technology direction**

By the mid-1990s, object oriented technology was taking the software industry by storm and Intergraph was no exception. At the May 1995 IGUG meeting, the company announced a major new initiative called Jupiter (named after the Florida city where Meadlock had a home and where the plan for this software was conceived in 1993) that would be used as the base for future applications. Knowledge about Jupiter had been restricted to a small group of individuals and when it was announced at IGUG many Intergraph marketing and development people had little idea how it fit into their specific plans.

In addition to its own Jupiter technology, Intergraph worked closely with Microsoft and other graphics software vendors interested in expanding Microsoft's OLE (Object Linking and Embedding) technology to handle three-dimensional objects. This extension to OLE was called OLE for Design & Modeling Applications (DMA) and was the rationale for establishing an industry organization called the Design & Modeling Applications Council (DMAC). Among the other companies involved were Autodesk, Bentley, SDRC, and Spatial Technology.

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[68] *Engineering Automation Report*, June 1995, Pg. 6
[69] *Engineering Automation Report*, November 1995, Pg. 3

The intent was to be able to handle mechanical assemblies or AEC models where individual objects were created by different applications. When the user selected a particular item, that action would initiate the appropriate design software. The integration of Jupiter with Windows' OLE for DMA sent the clear message that Intergraph had no intention of implementing Jupiter on any UNIX platforms. DMAC fell apart when it turned out that Intergraph held a patent for certain aspects of this technology and the other vendors were unwilling to go along with licensing terms proposed by Intergraph.[70]

It was becoming increasingly obvious that Intergraph planned to create an entirely new product line of applications built around Jupiter rather than MicroStation. Jupiter enabled applications were to be developed that communicated directly with the Windows operating system and did not require a CAD system such as MicroStation to handle graphical input, menu selections and display functions. Some people described the need to use a CAD system to support applications as a "CAD tax."[71]

At IGUG '95 Intergraph showed off prototypes of two Jupiter applications. The first was Imagineer Technical, a two-dimensional sketching program that was expected to sell for less than $1,000 per copy.[72] Eventually, this package would be renamed SmartSketch. The other application was a mechanical design product that was simply referred to as MD. It used Spatial Technology's ACIS geometric kernel together with Jupiter development tools. Rather than try to convert I/EMS to the new Jupiter environment, Intergraph had decided to make a fresh start. *Engineering Automation Report* had an extensive article on Intergraph's new software strategy in its June 1995 issue.

> "We are in solid agreement with the general strategic directions Intergraph is taking. The Jupiter technology recognizes the underlying flow of technology that is taking place in the computer industry. In particular, much of the actual code incorporated into legacy CAD systems is redundant with the software functionality found in the latest operating systems. And with Intergraph's strong relationship with Microsoft, they probably have a pretty good insight into where Microsoft is going.
>
> During the past 15 years, the most significant new CAD developments have come from startup companies such as Autodesk, Parametric Technology and Mentor Graphics which had the luxury of being able to start 'with a clean pad of paper.' Established vendors were forced to split their development resources between maintaining legacy software and implementing new ideas.
>
> Unfortunately, the new ideas were frequently just glued on the side of the existing products. Jupiter is one of the few attempts we have seen where an established vendor is attempting to create totally new technology and at the same time maintain application level compatibility with existing applications."[73]

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[70] Versprille, Ken, *Engineering Automation Report*, October 1998
[71] *A-E-C Automation Newsletter*, August 1997, Pg. 10
[72] Imagineer Technical was actually introduced at just $279 per copy for a short period of time before settling at $495.
[73] *Engineering Automation Report*, June 1995, Pg. 6

These comments were made two years before Clayton Christensen wrote *The Innovator's Dilemma* which succinctly described the problems companies have trying to satisfy the needs of existing customers while, at the same time, creating innovative new products. Intergraph was a perfect example of Christensen's analysis.[74]

At IGUG '95 it appeared that Intergraph planned to replace all MicroStation-based applications with Jupiter technology. A year later the attitude softened somewhat and the company stated that it planned to continue supporting MicroStation applications for the foreseeable future. Part of the reason behind this change in attitude was input from users who indicated that they had little desire to make the switch. [75]

MD was formally announced as Solid Edge in the fall of 1995 and released in April 1996. Priced at $5,995, it appeared that Intergraph planned to go after PTC and its Pro/Jr. product. Some of the key characteristics of this new package were:

- Solid Edge was oriented towards the design of assemblies rather than just individual parts.
- The user interface was Windows compatible, greatly reducing learning time.
- Use of OLE for DMA enabled users to insert MicroStation, EMS and AutoCAD parts in Solid Edge assemblies.
- Sketching tools automatically recognized constraints such as parallel and perpendicular lines.
- The transition for I/EMS users was expected to be a problem since EMS only ran on UNIX platforms and Solid Edge was a Windows application. Also, the analysis and manufacturing applications provided with EMS were not available for use with Solid Edge, either from Intergraph or third party software developers.[76] Intergraph did team up with ANSYS to offer analysis software that seamlessly worked with Solid Edge.

Solid Edge Version 2 was released in October 1996. It incorporated ACIS 2.0 which itself had a significant number of functional and performance enhancements. Rather than mount a frontal attack on the major mechanical software vendors, Intergraph was focused on two aspects of the design process, individual part design and the management of large assemblies.

Part modeling included the ability to design parts with open profiles – i.e., profiles with one or more contiguous elements missing. Solid Edge could also create parts starting with disjointed components and then fill in the gaps between these components. The assembly modeling was structured so that a user could model a part while working with the assembly, taking key dimensions from other parts.[77] NASA'a Marshall Space Flight Center in Huntsville was an early user of Solid Edge Version 2 acquiring 130 seats in December 1996.

Around this time Intergraph became increasingly agnostic regarding the base graphics systems used to support its applications. No longer married exclusively to Bentley's MicroStation, the company began to market applications that worked with

[74] Christensen, Clayton, *The Innovator's Dilemma*, Harvard Business School Press, 1997
[75] *A-E-C Automation Newsletter*, May 1996, Pg.10
[76] *Engineering Automation Report*, November 1995, Pg. 1
[77] *Engineering Automation Report*, November 1996, Pg. 11

 

Autodesk's AutoCAD software as well as with MicroStation. The first of these Jupiter-based applications that worked with AutoCAD as well as MicroStation were InRoads and SiteWorks which were released in early 1996.[78]

Eventually, the company began to call this ability to use different CAD systems in support of its civil engineering software SelectCAD and the company soon added IntelliCAD 98 to the CAD packages it supported. Intergraph also began to demonstrate AutoCAD at tradeshows running on its PC products which probably drove the wedge between it and Bentley even deeper.

The transition away from the high-margin Clipper workstations was beginning to show on Intergraph's revenues and earnings. The company was consistently loosing money each quarter, although typically not a great deal. Revenue, which had exploded in the 1980s was fundamentally flat throughout the 1990s. In the third quarter of 1996, for example, Intergraph's revenues were down 1 percent at a time when competitors such as SDRC, Dassault and PTC were experiencing growth rates in the range of nearly 30 percent to almost 50 percent.

**Focus shifts to information management**

Intergraph announced an object-oriented information management product, DM2, in late 1995 based on Metaphase. (see Chapter 17). Two of the first users were DuPont and the Navy's CAD-2 NAVFAC project. A year later the company emphasized the significance of this activity by establishing an Information Management and Foundations division under the direction of executive vice president Rich Buchheim. DM2 was subsequently renamed Asset & Information Management (AIM). A new version that added workflow and configuration management to the existing information management capabilities was announced in late 1996 for delivery in early 1997. By mid-1997, the company had installed AIM software at over 130 customer sites.[79]

AIM was a classical client/server implementation that was supported on Sun and HP UNIX workstations as well as Intel-based PCs and servers. Intergraph developed a series of industry-specific features on top of the basic Metaphase software. These were tailored for specific industry segments through the creation of data and processing models or templates.

For example, one of the first such templates was for the plant design and operating industry. It was called Plant Data Management Environment (PDME). A similar solution was developed for manufacturing industries. AIM also used the Active/CGM technology developed by the company's InterCAP subsidiary as described elsewhere in this chapter.

**Becoming a player in the graphics market**

Almost from the day it first began manufacturing computer terminals, Intergraph created significant internal expertise in the area of graphics hardware. Throughout the 1980s, the company's systems had some of the best graphics performance available. While the company was designing and manufacturing its own graphics processors, competitors were increasingly switching to commercially available devices typically produced by the same manufacturers from whom they purchased the workstations.

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[78] *A-E-C Automation Newsletter*, March 1996, Pg.13
[79] *Engineering Automation Report*, June 1997, Pg. 15

In early 1990, Intergraph introduced the EDGE product line of graphics processors. The EDGE-1 displayed 110,000 two-dimensional vectors per second while the EDGE-2 displayed 400,000 two-dimensional or 350,000 three dimensional vectors per second. Both handled 256 colors. An InterPro 6040 workstation with the EDGE-1 graphics sold for $29,900 while an InterPro 6280 with a new 60-MHz Clipper processor and EDGE-2 graphics sold for $45,900.[80]

Before 1990 was over, Intergraph substantially increased the graphics performance of its lower-priced workstations. The previously described Model 2020 with a 12.5 MIPS Clipper microprocessor supported 360,000 two-dimensional vectors per second. Intergraph sold 500 of these units to Sandia laboratories to support electronic design as well as a large number to Brown & Root as part of a $7.9 million contract.[81]

At this point in time, the company's workstation sales were about 90 percent single screen InterPro units and only 10 percent dual-screen InterAct systems.[82] Customers had mixed emotions about Intergraph's dependency on its own microprocessor technology. User comments ranged from "We like the fact that we can pick up the phone to a single source vendor and get service. It ends the finger pointing" to "For the long term I feel a little uncomfortable."[83]

The EDGE graphics subsystems were followed by the GT series. Introduced in early 1992 , the GT+ produced 760,000 two-dimensional and 530,000 three dimensional vectors per second when installed in a 2730 workstation while the GT II handled 830,000 two-dimensional and 640,000 three dimensional vectors per second in a 6750. The top-of-the-line EDGE product, the EDGE II+ had comparable vector performance to the latter unit but also handled 50,000 Gouraud-shaded polygons per second when used with a 6780.

The performance of Intergraph's display processors was somewhat dependent upon the speed of the computer to which they were attached. When attached to a higher-speed 6850, a GT II display was capable of 900,000 two-dimensional and 700,000 three-dimensional vectors per second.

When Intergraph began building Intel-based Technical Desktop systems, it also began producing some of the highest performance graphics accelerators available for PCs. These included the G90 and G91 that produced 600,000 two-dimensional vectors per second and the GLZ and GLI which added 250,000 shaded triangles per second, the latter unit with texture mapping.

In mid-1996 Intergraph became serious about the commercial PC graphics market. This interest was reflected in two ways. First, the company began developing a series of high performance graphics cards which were initially used on the company's own TD computer systems but eventually sold as add-ons for other vendor's machines. Second, Intergraph began pursuing the video industry with a combination of high-performance graphic systems and supporting software. In this later area, the company offered a combination of hardware and software called Studio Z. The system contained multiple PCI buses and Pentium Pro processors that were capable of handling broadcast quality video.

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[80] *The Anderson Report*, February 1990, Pg. 2
[81] *The Anderson Report*, September 1990, Pg. 2
[82] *The Anderson Report*, November 1990, Pg. 5
[83] *The Anderson Report*, November 1990, Pg. 5

To some extent it became difficult to separate Intergraph's interest in high performance personal workstations from its work on graphics accelerators. In July 1996 the company introduced three new workstations, the TDZ-310, TDZ-410 and the TDZ-610 with one (optionally two), two or four 200-MHz Pentium Pro microprocessors respectively. New graphics accelerators were labeled the Z10,Z13 and Z25.

The top-of-the-line Z25 produced 1.25 million shaded triangles per second and could be equipped with up to 64MB of optional texture mapping memory. While an entry level TDZ-310 cost $9,995, a fully equipped TDZ-610 could set a customer back $70,000 or more. Unfortunately, there was little Windows-based CAD software on the market that could take advantage of the multi-processing capabilities these machines offered. According to *Engineering Automation Report*:

> "Intergraph is going through somewhat of an identity crisis. Most of the media and many potential users see these systems as simply souped-up PCs and tend to compare them to other Pentium Pro systems offered by Compaq and Gateway 2000. Intergraph sees them as cost effective alternatives to RISC-based workstations sold by Silicon Graphics, Hewlett-Packard, etc. *EAReport* believes that they fall into the latter category and that you need to understand that these are not simply PCs on steroids."[84]

Several months later, Intergraph expanded its PC product line to include several lower priced machines, the TD-20 and the TD-200 which used standard Intel motherboards. With a 17-inch monitor, the TD-20 started at $2,590.[85] The company even began selling preconfigured systems using an 800 toll-free number in May 1997. Prices for these systems started at just $1,899.

In October, 1994, Intergraph acquired InterCAP Graphic Systems, a vendor of technical illustration software that also had significant experience working with CGM (Computer Graphics Metafile) software, for about $10 million. CGM is an international standard that supports both vector and raster two-dimensional data in a single file and was one of the key components of the Department of Defense's CALS initiative.

Dr. John C. Gebhardt, the company's founder and chief technical officer, was one of the country's leading experts on CGM. InterCAP subsequently adapted the CGM format for the Internet, calling it ActiveCGM. Within a few months, it was fairly obvious that Intergraph was interested in InterCAP more for its CGM expertise than for its technical illustration software. Intergraph only owned InterCAP for a few years, selling it in April 1999 to Micrografix for $12.5 million in cash and securities.

### Establishing a new generation of software

Intergraph Software Solutions (ISS), the software portion of Intergraph, was headed by Tommy Steele who both president of ISS and an executive vice president of Intergraph itself. He held this position until late 1997 when he left Intergraph to become

[84] *Engineering Automation Report*, August 1996, Pg. 4
[85] *Engineering Automation Report*, December 1996, Pg. 10

president and CEO of CyberGuard, a network security firm.[86] A significant portion of ISS was focused on the mapping and utility markets. Called Intergraph Infrastructure Software Solutions, it was headed by executive vice president Dr. Eddie Boyle while Preetha Pulusani was executive director of marketing. A few years later, Pulusani would end up running this portion of the Intergraph enterprise.

The Process & Building Solutions division was headed by David Stinson. Stinson was a former vice president of engineering at the Tennessee Valley Authority. By this point in time, Intergraph was de-emphasizing architectural software. According to Meadlock, there simply was no money to be made in that segment of the CAD industry.

With the launch of the new Jupiter technology Intergraph set out to recruit third party software firms that could provide applications in support of Intergraph's base mapping products. The newest GIS technology was called GeoMedia. It was a complete stand-alone product by itself but also provided integration with third party products such as Oracle's Spatial Data Option and subsequent versions of this database technology.[87] Intergraph recruited over 50 third party software firms to add capabilities to the GeoMedia product line by early 1997.

Indicative of the large projects Intergraph's mapping products were being used for was the development of a seamless cadastral database for the Province of Ontario, Canada. The actual work was done by Teranet Land Information Services of Toronto which was working on producing a database of nearly four million property parcels. By mid-1997, the company had produced maps coving 2.2 million properties and had loaded over one million parcels into a database utilizing Intergraph's MGE technology. Teranet was also using GeoMedia and AIM.[88]

The Infrastructure group was also responsible for Intergraph's civil engineering software. By 1997 there were over 12,000 seats of the company's InRoads software in use worldwide.

At the June A/E/C SYSTEMS '97 conference in Philadelphia, Jim Meadlock and Keith Bentley shared the conference keynote presentation with Carol Bartz, the CEO of Autodesk. This was where Bartz described her position on the podium as "a rose between two thorns." The animosity between Intergraph and Bentley was increasing on a regular basis to the point where Meadlock described it as a love/hate relationship. Since Intergraph still owned 50 percent of Bentley, whenever Bentley beat out Intergraph at a particular account, Intergraph still won, although not as much as if they had received the order.

At a press conference following the keynote Meadlock responded to media comments that the company seemed to be moving slowly replacing its MicroStation-based AEC applications with Jupiter-based software. He stated that what Intergraph was doing was filling in the gaps with new Jupiter software rather than simply replacing existing MicroStation-based applications and that once this was done, the company would move ahead replacing the legacy packages.

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[86] Steele subsequently ran into trouble regarding improper revenue recognition issues while president of CyberGuard and was the subject of an SEC administrative proceeding.

[87] Oracle's Spatial Data Option was subsequently supplemented by the Oracle 8 Spatial Cartridge. Today, this technology is simply an integral component of the Oracle database management software.

[88] *A-E-C Automation Newsletter*, October 1997, Pg. 3

 

He made it clear that plant design would be the last area to see Jupiter software and that PDS would be around for some time. When I asked him to provide some detail as to how Intergraph intended to regain profitability (it had lost money virtually every quarter since the early 1990s), his response was a brusque “You will see next quarter.”[89]

**Restructuring Intergraph**

The end of 1997 saw the beginning of a series of major changes at Intergraph. On one hand, the company began to focus on a narrower set of industry segments and announced a new mechanical joint venture with EDS that eventually led to the outright sale of the mechanical division. It was fairly clear to nearly everyone that EDS was primarily interested in Intergraph’s Solid Edge software rather than the I/EMS product line.

This acquisition got started when Intergraph began talking to EDS’ Unigraphics Division about using Parasolid as the geometric kernel for Solid Edge in place of Spatial’s ACIS. Once that decision was made, it led to an initial plan to create a new company that would be jointly owned by EDS, Intergraph and the company’s employees. The deal didn’t work out quite the way it was originally planned. In January 1998, EDS decided to set up the Unigraphics activity as a separate entity called Unigraphics Solutions (UGS). This business enterprise then acquired Intergraph’s mechanical activity for about $100 million. Dassault Systémes had acquired Solid Works a few months earlier for $310 million and since Intergraph had roughly the same size installed base for Solid Edge, one could say that EDS got a bargain. As part of this deal, UGS took on the responsibility of supporting Intergraph’s I/EMS customers, especially those that resulted from the Navy’s CAD-2 contracts.

The second reorganization was the establishment of the company’s computer hardware operation as a separate business unit called Intergraph Computer Systems with its own profit and loss responsibility with Wade Patterson as president. This move became effective January 1, 1998. Supposedly, while Intergraph owned the majority of ICS stock some was being reserved for the employees of the operation.

ICS put on a hard push in 1998 to provide PCs with some of the best graphics capabilities available in the industry. The company’s TDZ 2000 3D Graphics Workstation with RealiZm II was particularly powerful at the time, outperforming similar machines from Compaq and Hewlett-Packard and even UNIX workstations such as SGI’s OCTANE R10000.[90] A few months later, ICS introduced a even higher performance dual processor machine called the TDZ 2000 GT1 that had peak memory bandwidth of 1.6GB/second. One of the problems with this technology was that there was very little CAD software other than some analysis and visualization programs that took advantage of multiple processors.

The next step in this restructuring was to take the group within ICS that specialized in high performance graphics cards and set it up as an independent business unit, similar to what had been done earlier with VeriBest. Called Intense3D, it was headed by Jerry Peterson[91] who previously had been vice president of engineering for

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[89] *A-E-C Automation Newsletter*, July 1997, Pg.2 and personal recollection

[90] *A-E-C Automation Newsletter*, March 1998, Pg. 13

[91] Peterson was employed by AutoTrol Technology in the early 1980s, working on that company’s advanced graphics hardware. He then went on to work at Tektronix before joining Intergraph.

 

ICS. At the time, this group was a major vendor of high-end graphics accelerators used on computers produced by Dell, Compaq, IBM and Fujitsu as well as Intergraph. Intense3D's primary product was its Wildcat graphics accelerator.

At SIGGRAPH '99 in Los Angeles, the company introduced the Wildcat 4110 that rendered up to six million triangles per second. This was one of the first commercial devices that was capable of volumetric texture mapping which enabled cross-sectional texturing of three-dimensional objects.

Between 1990 and 1998 Intergraph's revenues had stagnated at a little over one billion dollars and after earning $8.4 million in 1992, the company lost a total of $320 million during the next six years. Only the occasional quarter was profitable during that period and the worst was yet to come. In the August, 1999 issue of *A-E-C Automation Newsletter*, I wrote a front-page editorial that recommended that Intergraph get out of the PC hardware business and concentrate on the software applications that were its strong suit. Little did I know how close Intergraph was in doing just that.[92]

Intergraph's most significant restructuring announcement came on September 2, 1999. According to Jim Meadlock, "Intergraph is a technical solutions and systems integration company made up of business units that provide customizable core software and services to our chosen markets."

The following specific actions were announced by the company:

1. The company was reorganized into nine business units, each addressing the needs of specific industries or markets in which Intergraph was an established leader or had long-term potential. The systems-oriented business units are described below.
2. Intergraph would exit the generic PC and server business, which according to the company, suffered irreparable harm from the Intel actions which were the basis of its then current lawsuit against Intel as described later. These were the machines that carried the TD brand. ICS made a specific point with the media that the company planned to continue marketing its TDZ and Zx workstations. The company had sold its PC manufacturing operation in late 1998 to Huntsville's SCI Systems[93], a rapidly growing contract manufacturer.
3. It planned to strengthen its high-end workstation and graphics accelerator businesses by seeking partners with complementary technology and sales channels for Intergraph Computer Systems' ViZual Computing and Intense3D units. It appeared to *Engineering Automation Report* at the time that if another company made the right offer, these two units could well be sold off. In a separate deal, Intergraph had recently sold its ANAtech scanner division to Colortrac.
4. Intergraph stated that it would strengthen VeriBest's value and market reach by seeking partners with complementary technology and sales channels in the electronics design automation market. Less than two months later, on October 31, 1999, Intergraph sold VeriBest to Mentor Graphics.
5. To accelerate the pace of forming these partnerships, Intergraph's president and COO Manfred Wittler was given the task of coordinating partnering discussions with other companies. Wittler had become president and COO in May after spending ten years in Intergraph's sales and marketing organizations.

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[92] *A-E-C Automation Newsletter*, August 1999, Pg. 1

[93] Known today as Sanmina-SCI

6. Intergraph planned to cut expenses across the board in order to bring costs in line with revenue. As part of that effort, the plan was to eliminate about 400 jobs worldwide. This would result in a special charge of $20 million in the current quarter. It would turn out to be just the first of a string of special charges resulting from restructuring the company.

Meadlock tried to paint the need to make these changes on contractual issues with Intel. I believed that the real cause of the company's problems with its ICS operation was the lack of an effective distribution organization. In reality, while the problems identified by Intergraph where Intel was slow in providing technical information on new microprocessors were annoying, it generally did not stop the company from introducing new systems in a timely manner. When Intel introduced its new 600-MHz Pentium III, Intergraph was right there with other PC vendors offering new machines using this microprocessor the same day.

The actual structure of this reorganization changed during the following months and by early 2000 the new systems oriented divisions and their leaders were:

1. **Mapping/Geographic Information Systems (Preetha Pulusani) -** included software products for civil engineering, photogrammetry, mapping/GIS, imaging, plotting and scanning support.
2. **Public Safety (Roger Coupland) -** public safety solutions for integrating police, fire and emergency services.
3. **Process & Building (Dave Stinson) -** with a nearly 60% market share in 3D plant design, Intergraph was the clear leader in this industry sector. This division was also responsible for the specialized Intergraph software used by shipbuilding companies.
4. **Communications (Arthur Spencer) –** developed and sold geospatial solutions for the telecommunications industry.
5. **Utilities (Kevin Hitt) –** provides geospatial and information management solutions to gas, electric, pipeline and water utilities.
6. **Federal Systems (William Salter) -** this business unit provided off-the-shelf and specially developed products and services to federal government agencies around the world.
7. **Z/I Imaging (Lewis Graham) –** established in August 1999, this new company combined the photogrammetry divisions of Carl Zeiss and Intergraph into a new jointly owned company called Z/I Imaging.[94] This venture was 60 percent owned by Intergraph and 40 percent by Zeiss.

By late October 1999, Intergraph's stock price had dropped to just $3.25 per share. Wall Street was probably a little premature in writing off the company. Intergraph actually made a profit of $3.6 million in the fourth quarter of 1999, primarily due to a gain of $14.4 million on the sale of Veribest. Revenue, which was down to $224 million in the last quarter of 1999, would continue to fall in succeeding years as the company struggled to turn itself around. From 1995 through 1999 shareholder equity dropped from $504 million to $277 million due to the losses the company was incurring. What Wall

[94] *Engineering Automation Report*, October 1999, Pg. 1

 

Street was missing was Intergraph's 50 percent ownership of Bentley Systems which was still privately held and the fact that Intergraph's case against Intel and various PC manufacturers had more life to it that they gave it credit.

The next major development occurred on March 2, 2000 when Jim Meadlock turned the CEO title over to Jim Taylor. Taylor was the first non-founder to join the company in 1969 and had been on Intergraph's board of directors since 1976. He had "retired" from Intergraph in 1992 but returned in 1995 to head the newly formed Public Safety business unit. Meadlock retained his position as chairman of the board and made it clear that he intended to focus on the Intel lawsuit. At the same time, Nancy Meadlock retired from the company. Manfried Wittler, who many thought would be the next president of Intergraph, retained his position as CEO of Intergraph Computer Systems having replaced Wade Patterson at the beginning of 2000.

## The breakup continues

In measured steps, Intergraph continued to extract itself from the hardware business. In April 2000, the company announced plans to sell the Intense3D operation to 3Dlabs for 3.69 million shares of 3Dlabs stock then worth about $26 million. The deal also called for Intergraph to receive up to an additional $25 million based upon the performance of the Intense3D unit during the remainder of 2000. About 95 Intense3D people became employees of 3Dlabs as a result of this acquisition. 3Dlabs eventually exited the graphics accelerator market in 2006.

The next step was to work out a deal with Bentley Systems under which Bentley acquired Intergraph's InRoads suite of civil engineering software, the company's InterPlot and Digital Print Room software and its I/RAS raster editing applications. Bentley paid Intergraph about $42 million for these applications, $14 million up front and the balance over time. There were approximately 100 Intergraph employees involved in developing and supporting these applications, a number of whom were subsequently hired by Bentley. The agreement also called for Intergraph to continue acquiring MicroStation/J and related applications from Bentley for resale to its customers.

One additional move was to sell off the company's architectural design software products in June 2000 to a new organization, AEC DesignWare, headed by a long-time Intergraph marketing executive, Tom Zurn.[95] Then in July, Intergraph announced a deal with SGI under which it would purchase $100 million in SGI products and services over a period of three years and SGI would acquire Intergraph's remaining PC and server products. The Zx10 product line would be marketed exclusively by SGI which had recently introduced its own Intel-based computer systems. With this move, Intergraph was now out of the hardware business and was strictly a software and services company.[96]

## The new Intergraph

By September 2000, the restructuring of Intergraph was virtually complete. Hardware elements of the company had either been sold or were in the process of being sold and non-core software product lines including architecture and civil engineering were also going or already gone. What was left was still one of the largest software and

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[95] *A-E-C Automation Newsletter*, July 2000, Pg. 15
[96] *Engineering Automation Report*, August 2000, Pg. 14

 

system integration companies in the technical computing marketplace. The divestitures had the effect of reducing overall corporate revenue but were expected to result in a profitable company, something the company had been unable to accomplish consistently for far too many years.

Intergraph restructured itself into six independent divisions, each with its own profit and loss responsibility and with independent business strategies and plans. The business units were Intergraph Public Safety; Intergraph Utilities & Communications; Intergraph Government Systems; Intergraph Mapping/GIS; Z/I Imaging; and Intergraph Process & Building Solutions (PBS).

Not many people realized quite how large of an operation PBS had become. Once it was an independent division, its financial numbers were reported separately rather than just commingled with the entire Intergraph business. Those numbers showed a profitable business entity with over 1,000 employees and more than $180 million in annual revenues. That made PBS a substantial business activity in its own right, about the same size as Bentley Systems at the time and four and a half times the size of Cadcentre Group, its nearest competitor in the plant design arena.

According to Daratech, Intergraph had a 59 percent share of the three-dimensional plant design and visualization market in 2000 and 26 percent of the drawing-centric portion of the market. The total combined market for plant design software and services in 2000 according to Daratech was about $270 million. Intergraph's share of the three-dimensional portion had been steadily increasing in prior years while its portion of the two-dimensional market had jumped significantly due to new software.[97]

In addition, Dave Stinson was promoted to president of PBS in May 2000 when this organization was changed to an independent Intergraph division with its own profit and loss accountability. Other key individuals in PBS were Kurt Ingenthron, a 22-year Intergraph veteran who was the division vice president of product development and its chief technical officer, Ed Edmondson, who had recently joined the division from Black and Veatch as executive vice president and chief operating officer, and Shiraz Jaffer, the former president of EA Systems, who was vice president of marketing.[98]

In the mid-1990s Intergraph began supplementing its PDS software with new applications using the SmartPlant nomenclature. One of the first of these was SmartPlant Explorer which enabled users to browse through PDS P&ID and instrument data as well as data from non-Intergraph systems using Microsoft's Internet Explorer. This was followed by a new SmartPlant P&ID package.

Early 1999 saw Intergraph ink an agreement with Aspen Technology to interface the latter company's plant simulation software with SmartPlant P&ID. Intergraph also acquired a small software firm, Design & Software Industries, that developed software for the design and maintenance of process instrumentation.

The Process & Building Solutions Division's software was undergoing rapid transformation at this point. Most of the software customers were using, however, dated back to the previously described PDS product. These were all MicroStation-dependant applications that were gradually being replaced by new SmartPlant packages. As described earlier, these included SmartSketch (new name for Imagineer Technical), SmartPlant P&ID, SmartPlant Explorer and in early 2000, SmartPlant Review. The latter

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97 Daratech, Inc., Cambridge, MA, Undated press releases
98 Intergraph Press Release, May 8, 2000

 

package was a successor to earlier Intergraph visualization products including DesignReview and SmartPlant Viewer.

The company made a point of the fact that SmartPlant Review was not just for viewing PDS models but could also be used to navigate through three-dimensional models created with MicroStation, AutoCAD or Solid Edge without the need for any data translation. Review used a standard Windows interface to enable users to navigate models up to 300MB in size.

The major development effort at the time was focused on plant modeling software. Called SmartPlant 3D, it would enable multiple users to work on the same section of the plant with each seeing what the others were doing. This approach eliminated the need to break the plant into multiple sections in order to avoid conflicts. Clash detection ran continuously in the background, immediately alerting users when there was a design problem. The software also incorporated parametric design capabilities. If one aspect of the design was changed, related objects changed accordingly. For example, if the height of a pump was changed, the foundation and connecting piping would adapt to its new position.

This software was heavily database oriented. Intergraph offered two data management tools, Directa which was a document and asset management tool and Notia which was used primarily to support plant operations.[99]

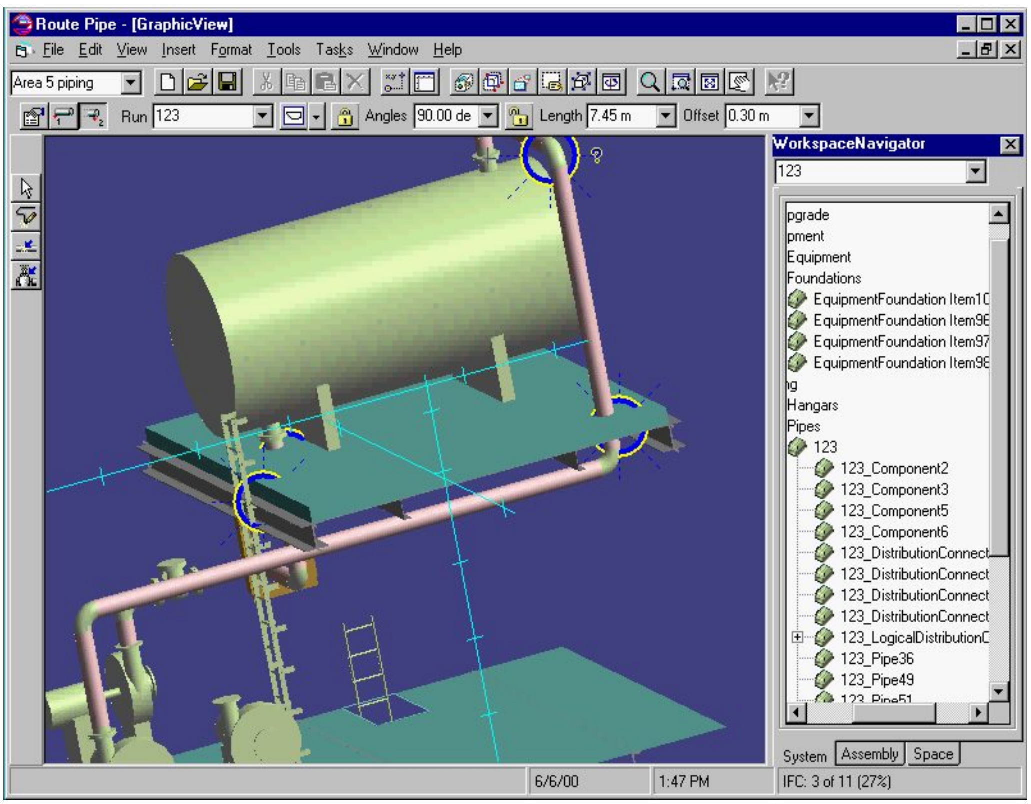


Figure 14.3
SmartPlant 3D

[99] *Engineering Automation Report*, September 2000, Pg. 6

**Intergraph as a pure software company**

Once all the hardware elements of the company had been sold off, Intergraph concentrated on re-establishing its reputation as a vendor of high-end technical software, particularly in the plant design arena. The Process & Building Solutions division was soon renamed the Process, Power & Offshore division now that the company was no longer marketing architecture software. Although I was shown a prototype of SmartPlant 3D in 2000, it was the fall of 2003 before it was ready for broad customer installation.

Intergraph recognized the fact that this was complex software and implementing it would tax the technical abilities of most user organizations. It therefore put together what it called the *Early Adopter Program* that consisted of a mix of SmartPlant 3D software and consulting services. While the version I saw demonstrated a few years earlier focused on the actual design process, the released software was significantly more database oriented.

An underlying SmartPlant 3D concept was that the people working on the design and construction of a complex plant or offshore facility would typically be located in multiple offices, possibly spread around the world. Coordinating the design work resulted in the concept of using replicated databases at each design and construction center. When a designer at one location made a change, that change was transmitted to all the other sites as a transaction. Keeping all the databases synchronized was not a major communications problem because each of these transactions typically represented only a small amount of data.

One concern was what would happen if the communications to a remote site were inoperative for a period of time? Would the people at that location be unable to work due to the communication failure? That is what would have happened if everyone was working off a single central database. The worse that would happen at the remote location in this situation was that they would work with the local data until communications was re-established at which point the remote database would be updated and any conflicts caused by this worked would be flagged so they could be resolved.

**Intergraph sues Intel over patents[100]**

On November 17, 1997, Intergraph filed a 22-count lawsuit against Intel that alleged that Intel applied undue pressure on Intergraph to grant Intel rights to certain microprocessor patents regarding cache memory management and that when Intergraph refused, Intel withdrew expected technical support, delaying the introduction of Pentium II workstations. Needless to say, Intel had a different opinion about these matters. On December 3, 1997 Intergraph amended its complaint to include a count charging Intel with violations of federal antitrust laws.

The patents in question go back to September 1987 when Intergraph purchased the Advanced Processor Division ("APD") of Fairchild Semiconductor. APD produced the Clipper RISC-based microprocessor described earlier that Intergraph used in its UNIX workstation and server products. As part of this acquisition, Intergraph acquired

[100] The entire Intergraph/Intel patent dispute as well as Intergraph's lawsuits against other computer vendors is an extremely complex story that is far too detailed to be covered in this book. It really has little to do with the development of engineering design technology. As a consequence, I have decided to simply cover the highlights of this long drawn-out legal dispute.

 

the rights to technology that resulted in patents eventually being issued in 1990 and 1992..

As also mentioned earlier, National Semiconductor acquired the bulk of Fairchild at the same time Intergraph acquired APD. Intel had a technology sharing agreement with National and claimed that as a consequence it had rights to this technology. To a certain extent, the case revolved around whether Intergraph acquired the APD directly from Fairchild or from National after it acquired all of Fairchild Semiconductor.

In its complaint and related material, Intergraph describes its relationship with Intel from 1992 through 1996 as particularly harmonious where the two companies readily shared technical information concerning the implementation of computer systems using the latest Intel products. In fact, when Intel launched the Pentium Pro in late 1995, the company used Intergraph workstations at the product launch.

According to Intergraph, the turning point in the relationship occurred when Intel inquired about rights to the Clipper patents, particularly one or more related to microprocessor memory management. The complaint stated that Intel basically wanted access to these patents simply in return for providing Intergraph with proprietary information about new microprocessors. When Intergraph refused to accede to Intel's request, the complaint stated that Intel began to withhold technical information from the company and otherwise interfered with Intergraph's business activities. Intergraph subsequently held that this delayed new product introductions by up to six months and that it was late 1998 before the company's products were technically in line with its competitors.[101]

Intel's side of the story was quite different. In a conversation shortly after the lawsuit was filed, an Intel spokesperson, Chuck Malloy, told me that Intergraph actually fired the first shot when it began to assert patent rights against other computer manufacturers in late 1996 but not against Intel. These manufacturers asked Intel to resolve the issue. Discussions went on between the two companies up through the week before the suit was filed. Apparently a settlement offer was made by Intel but not accepted by Intergraph. Intel also believed that the Clipper patents in question were not valid and the company filed its own suit in California to that effect. Intel did not deny that it cut off Intergraph from technical information concerning future microprocessors.

At the time Intergraph's lawsuit was filed, it was hard to take it very seriously. The expectation was that the dispute would soon blow over, the two companies would kiss and make up and perhaps Intel would pay Intergraph a few million dollars to make them withdraw the lawsuit. Little did most people realize how strongly Jim Meadlock felt about this issue, that the Intel lawsuit as well subsequent lawsuits against Hewlett-Packard, Dell and Gateway would drag out for over seven years and would result in Intergraph receiving hundreds of millions of dollars from Intel and the computer manufacturers.

Following is a rough chronology of the major events involving these lawsuits and settlements:

**April 10, 1998 –** Judge Edwin Nelson of the U.S. District Court, Northern District of Alabama ruled that while the lawsuit proceeded, Intel must provide technical information to Intergraph on the same basis that it provided that information to other

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[101] *Intergraph 1999 Annual Report*, Pg. 20

 

major computer vendors.[102] Intel appealed this ruling shortly thereafter. Subsequent to this ruling, Intel signed a consent decree with the Federal Trade Commission that it would not withhold such information from PC manufacturers while patent disputes were being resolved.

**June 17, 1998 –** Intel filed its answer to the Intergraph lawsuit claiming that Intergraph violated several Intel patents and Intel initiated what was subsequently called the "license defense," as described above.

**June 4, 1999 –** Judge Nelson ruled that Intel's license agreement with National did not give it rights to the intellectual property Intergraph acquired from Fairchild.

**August 1999 –** Intergraph filed a claim with the court that Intel was not providing technical information in a timely manner as required by the court.

**October 12, 1999 and November 5, 1999 –** Intergraph took a double hit when Judge Nelson reversed himself and ruled that Intel was correct when it held the position that it acquired rights to Clipper technology when it acquired Fairchild. Intergraph immediately appealed this decision. The United States Circuit Court then overruled the April 10, 1998 decision that Intel must provide technical information to Intergraph. In actuality, this later ruling had little effect on the immediate relationship between the two companies since Intel was bound by the FTC consent decree to provide such information to Intergraph. Unless overturned by higher courts, these two rulings left Intergraph with just its claims of coercive action on the part of Intel.[103]

**March 10, 2000 –** The Alabama Court dismissed Intergraph's antitrust claims against Intel.

**April 15, 2002 –** Intergraph and Intel settled the Alabama cache memory case and the lawsuit was dismissed. Intergraph transferred several patents to Intel and Intel agreed to pay Intergraph $300 million. The agreement also set terms for resolving a separate lawsuit involving parallel computing patents being heard in Texas. If Intel won the Texas lawsuit, Intergraph would not owe anything to Intel but if Intergraph won, Intel would pay $150 million and if Intel appealed the decision and lost the appeal, it would pay an additional $100 million.

**October 2002 –** The judge in the Texas case ruled in favor of Intergraph and Intel paid the company the $150 million it had previously agreed to. Intel did appeal this finding although the $150 million payment was non-refundable.

**December 16, 2002 –** Intergraph sued Hewlett-Packard, Dell and Gateway in United States District Court for the Eastern District of Texas claiming infringement of patents having to do with parallel instruction computing.

**January 2003 –** Intergraph resolved outstanding patent issues with IBM and the two companies signed a cross-license agreement.

**January 2003 –** Intergraph filed a lawsuit against Texas Instruments regarding parallel instruction computing.

**September 2003 –** Texas Instruments settled with Intergraph for $18 million.

**May 28, 2003 –** Hewlett-Packard sued Intergraph in United States District Court for the Northern District of California, San Francisco Division for infringing on patents related to computer-aided design, video display technology and information retrieval technology.

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[102] *Engineering Automation Report*, May 1998, Pg. 12
[103] *A-E-C Automation Newsletter*, December 1999, Pg.12

**March 30, 2004 –** Intergraph settled all outstanding issues regarding its parallel instruction computing lawsuit with Intel for $225 million. This settlement also resolved the lawsuit with Dell. After Intergraph had sued Dell, Dell in turn sued Intel claiming that that an earlier settlement between Intergraph and Intel absolved Dell of responsibility regarding these patents.

**May 14, 2004 –** Gateway settled with Intergraph for $10 million plus future royalties on certain computer systems.

**January 21, 2005 –** Hewlett-Packard settled with Intergraph for $141 million. This made the total of all patent settlements $860 million before considering Intergraph's legal fees which were considerable. The net amount was $768 million. A large portion of this was used to buy back company stock.

**Intergraph subject of leveraged buyout**

From a low of $501 million in 2002, revenues at Intergraph climbed back to $577 million in 2005. The company's stock recovered from a low of $3.19 in October 1999 to a high of $51.47 in December 2005. None of the founders were employed by the company at this point. The president and CEO was R. Halsey Wise who joined the company in that position in 2003. The company was now organized in two primary division, Process, Power & Marine under Gerhard Sallinger and Security, Government & Infrastructure under Ben Eazzetta. At the end of 2005, Intergraph had 3,450 employees, less than third what it had at its peak.

On August 31, 2006, Intergraph announced that it had signed a definitive agreement to be acquired by an investor group led by Hellman & Friedman LLC and Texas Pacific Group in a transaction valued at approximately $1.3 billion. Shareholders were to receive $44 per share in cash. The transaction in late 2006.

 

# Chapter 15

# Patrick Hanratty and Manufacturing & Consulting Services

No history of the CAD/CAM industry would be complete without an in-depth discussion about Dr. Patrick Hanratty and his software company, Manufacturing and Consulting Services (MCS). In many quarters, Hanratty is considered the “father of CAD/CAM.” This recognition was earned by the fact that software he developed at MCS and at a predecessor company, Integrated Computer Systems, was used by nearly a dozen companies as the basis for their commercial products in this market. In addition to licensing its software for resale, MCS, at various times over the years, also sold these tools directly to end users, some of whom are loyal users to this day. Of all the early developers in the CAD/CAM industry, Hanratty is one of the few who is still personally writing software in the 21st century.

Hanratty grew up in the San Diego area and like many of his cohorts went off to fight in the Korean War soon after high school. After spending over a year recovering from injuries suffered in Korea, he took a battery of tests as part of his rehabilitation and found that he was well suited for work in a scientific environment. Without a college degree, he managed to get hired by Convair in 1954 in San Diego as a programmer working on IBM 650 and UNIVAC 1103 computers. One typical project was to calculate the distance required for an aircraft to take off under various load conditions.

Describing himself as always restless, Hanratty responded to an ad placed by General Electric in 1956 for programmers in the Phoenix area. One of Hanratty’s early projects while at GE was the development of an early numerical control software package called PRONTO (Programme for Numerical Tooling Operations). It basically took machining statements that an NC specialist entered onto coding sheets and processed these statements in a batch mode after they had been keypunched into punch cards and produced the actual digital instructions the machine tool controller needed to operate the machine tool. PRONTO was a point-to-point NC package developed for the Kearney & Trecker Milwaukee 3 machine tool used at GE’s Schenectady, NY facility

Another program developed around the same time was the General Electric Machine Tool Director or MTD. This program handled limited 2 ½-axis contouring operations. It could machine parts at different Z levels, but it could not machine complex surfaces. Tool movements were defined in either absolute coordinate terms or symbolically. As an example, the part programmer could have the software determine where a straight line intersected a circular arc using a symbolic name for the point of tangency. NC machining was a relatively new manufacturing technique in the late 1950s and this was one of the first programs that facilitated programming these machines. These projects apparently initiated a life-long interest in NC machine control for Hanratty.

The actual group Hanratty was working for eventually became GE’s process control unit. (Ten years later, I would work closely with this GE organization developing a petroleum product movement control system for the Lago oil refinery in Aruba.). GE shipped Hanratty off to western Pennsylvania to work on control systems the company was installing at several steel plants. He worked on systems for rolling mills operated by

Jones & Laughlin and Bethlehem Steel. Along the way he completed his B.S. degree in mathematics from Arizona State University.

**Numerical control software development at GM**

In late 1962 Hanratty left GE and went to work for General Motors in Michigan. As he puts it, “good job, good salary and good benefits.” But he also found that GM was a hard place to sell ideas.

A misconception of which I am guilty of propagating along with many others, that Pat Hanratty was instrumental in the development of DAC-1, needs to be put to rest. Although he was employed by GM Research Laboratories from late 1962 to late 1966, DAC-1 was more a software development platform that he apparently used rather than a project he was intimately involved in. None of the papers published by DAC-1 participants mention him by name. One of the byproducts of working with the DAC-1 project team, however, was that he developed a relationship with several of the programmers on the project, among them Jerry Devere and Art Larsen, whom he would subsequently work with for a number of years. (See Chapter 3 for a detailed description of DAC-1.)

Hanratty’s work at GM focused mostly on numerical control software. His title was Corporate Coordinator for Numerical Control Research. The primary platforms he worked on were the 7094 with the DAC-1 display console followed by an IBM System 360 computer with 2250 displays. Hanratty feels that the most significant innovation associated with the 360 was IBM’s move to 8-bit code, replacing the earlier 6-bit code that had limited programmers to 64 different alphanumeric and special characters.

Shortly after joining GM, Hanratty became aware that the company was having problems producing tooling for the 1964 Cadillac trunk. He volunteered to produce the control tape for the NC machine that would make the die. His boss didn’t think it could be done in the six weeks available but Hanratty believed he could. This became a point of contention (actually it is hard to visualize Pat Hanratty taking orders from anyone). In order to get authorization to proceed, Hanratty wrote an undated letter of resignation and stated that if he failed, the letter would be effective. Even though he was also working on his masters degree in systems engineering at the time which he eventually received from West Coast University, he managed to complete the task on schedule. Not only was it done on time, but the styling studio was impressed with the quality of the tooling that was produced. There was no need to put a date on the letter. The tool paths for the trunk lid are shown in Figure 15.1. (This image is also reproduced in an article written for the *IEEE Annals of the History of Computing Vol. 16 No. 3, 1994* written by Fred Krull, one of the DAC-I project leaders.)

For the next several years Hanratty concentrated on taking complex surfaces and producing toolpath data for NC machines. As he describes it, these surfaces were described by $5^{th}$ degree polynomials which made it particularly difficult to machine surface edges. The surface data was taken off the stylists’ clay models using a scanner developed by IBM. Given the scanned data, Hanratty developed ways to define actual parts.

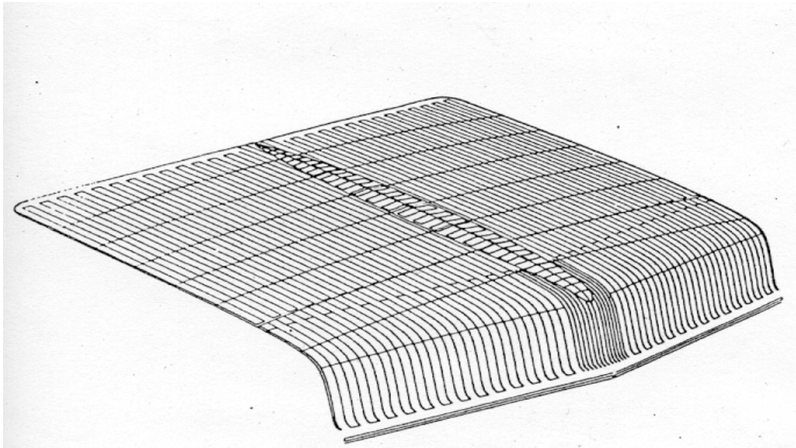

Figure 15.1
Trunk Exterior Toolpaths Created Directly from Math Data

**Back to California**

It was now time to move back to California. In early 1967 Hanratty went to work for Astronautics Corporation to help them develop computer-based design technology. For a while he continued to do work for GM on a consulting basis in areas such as surface machining technology. One particular project involved machining gears for the first collapsible steering column. This dual responsibility went on for about six months.

Eventually, Hanratty hired Jerry Devere, Art Larsen and several others from GM to work on software for mechanical and electrical design using a Xerox Sigma 7 computer with Tasker refresh vector graphics terminals. While this work was underway, Astronautics was acquired by McDonnell Douglas which had its own in-house CAD system, CADD, under development. According to Hanratty, this led to conflict between the two groups and eventually the work at Astronautics began to wind down.

**Developing his own CAD system**

Hanratty had been involved for eight years in developing CAD/CAM technology for large companies. At the end of 1969 he decided to set out to create his own software without having to fight corporate inertia. On January 2, 1970, with seven people from McDonnell Douglas including Devere and Larsen and $100,000, he started Integrated Computer Systems. They planned to develop a complete CAD/CAM solution on a REDCOR minicomputer using TPL (The Programming Language), an Algol-like programming language written by Larson. By that fall they were ready to show the software at the 1970 International Machine Tool Show in Chicago.

ICS demonstrated the entire cycle from design through drafting and NC tape preparation. Technically, the software was well received but potential customers objected to the use of TPL. As good of a programming language as it might have been, it had virtually no following. As an interesting sidelight, 13 years later Applicon would run into the same problem when it programmed BRAVO! in a proprietary version of PL-1. This goes to prove that users, particularly at large companies, are more interested in standard technology than trying to push the envelope with potentially better proprietary technology.

The ICS software product was called INTERAPT. Apparently the name was derived from its interactive capabilities and its focus on machine tool control since APT was an NC programming language that stood for Automatically Programmed Tools. INTERAPT contained a number of modules including:

- EUCLID – Basic three-dimensional geometric construction using either interactive graphics or a batch language.
- EXTENDED Euclid – Advanced three-dimensional geometric construction covering the standard surfaces supported by the APT NC programming language.
- ICAD-M – Interactive computer aided drafting – mechanical.
- ICAD-IC – Interactive computer aided drafting – integrated circuit.
- ICAM-2+ – Interactive computer aided machining in two-dimensions plus depth.
- ICAM-3 – Interactive computer aided machining in three-dimensions (this module supposedly also supported five-axis machine tools).
- DISECT – Dynamic interactive section properties.

Since this was nine years before Matra Datavision was founded, there was no conflict with that company's use of the EUCLID brand.

There are many features of INTERAPT that would show up in subsequent versions of Hanratty's design and NC software products including ADAM, AD-2000 and ANVIL. One consistent theme has been the ability to drive the software by means of a specialized APT-like language. Since interactive graphic terminals were very expensive in the 1970 time frame, the ability to design parts off-line, enter the geometric definition data on punch cards and then have the computer create a model of the part as a batch process was perceived to be an efficient alternative. In INTERAPT, this capability was known simply as the EUCLID Language Option. It evolved over the years into what was called GRIP (GRaphics Interactive Programming language) in ADAM as described below, and is known today as GRAPL-IV. Figure 15.2 illustrates a sample EUCLID part program while Figure 15.3 shows what the resulting part would look like.

```
PARTNO LANGO10
VIEW/1
ZSURF/.5
PT1=POINT/.5,0.0
LN1=LINE/0.0,.5,0.0,2
FIL1=FILLET/XLARGE,LN1,YLARGE,PT1,RADIUS,.5
PT2=POINT/1.25,3.25
PT3=POINT/DELTA,PT2,1.75,0.0,0.0
LN2=LINE/PT2,ATANGL,LN1,-45
LN3=LINE/PT2,PT3
FIL2=FILLET/YSMALL,LN2,XLARGE,LN1,RADIUS,.625,TRIM
FIL3=FILLET/YSMALL,LN3,YSMALL,LN2,RADIUS,.625,TRIM
LN4=LINE/PARLEL,LN3,YSMALL,.25
FIL4=FILLET/XLARGE,PT3,YLARGE,LN4,RADIUS,3
LN5=LINE/PARLEL,LN1,XLARGE,4.5
FIL5=FILLET/XSMALL,LN5,YSMALL,FIL4,RADIUS,.5
FIL4=FILLET/XLARGE,PT3,YLARGE,FIL5,RADIUS,3
PT4=POINT/END,YSMALL,FIL5
PT5=POINT/4.5,.25
LN6=LINE/PT4,PT5
STG1=STRING/PT1,X,2,Y,0,CCW,.25,90,(DY,.75),CW,.375,
     180,(DY,-.75),CCW,.25,90,X,4.25,Y,0,CCW,.25,90
DELETE/POINTS
DELETE/LN4,LN5
FINI
```

Figure 15.2
INTERAPT Part Program

 

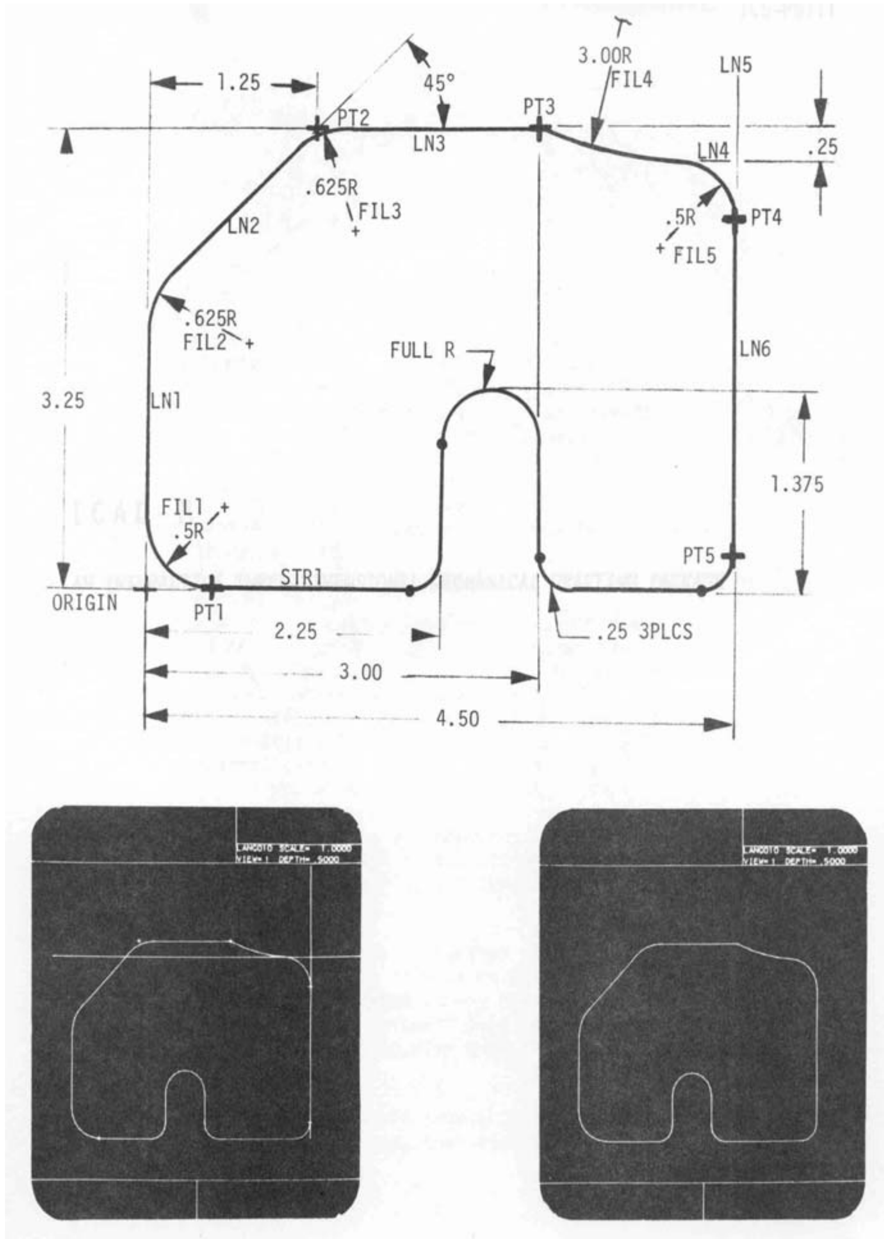


Figure 15.3
Part generated by program in Figure 15.2 – Lower left illustration shows construction points and lines while they have been deleted in lower right.

With few customers ICS was rapidly running out of money in early 1971. This was well before the days of venture capital firms spreading millions of dollars around like there was no tomorrow. TRW approached Hanratty about buying ICS, but he felt that the process of doing so would take too long and the company would be out of money before the acquisition could be completed. To the rescue came Systems Science and Software, commonly known as $S^3$.

With $S^3$ came a new player, Dr. David Albert, who had joined that company a short while earlier after working for the National Security Agency and receiving a Ph.D.

 

from Catholic University. Albert was doing some consulting work for Sandia Laboratories in Albuquerque, New Mexico and had channeled some electronic design development work to ICS. When ICS began to run out of money, Albert got $S^3$ interested in acquiring the company. This deal was completed around mid 1971.

$S^3$ offered all the ICS employees the same salary they had been making if they would stay with the company. Most accepted the offer. The assumption was that Hanratty would also stay to be the guiding force behind future software development. Such was not the case. Hanratty simply decided not to show up for work when $S^3$ took over. He called in that morning and resigned.

**MCS is born**

Several months later, on November 1, 1971 Hanratty formed Manufacturing and Consulting Services in Costa Mesa, California and set out to develop a new machine-independent version of the software that been started at ICS. This soon became known as ADAM, Hanratty's idea of it being the first in a new generation of design and manufacturing software packages. ADAM also stood for Automated Drafting And Machining. The package was initially written for the 16-bit REDCOR RC-70 minicomputer which was first delivered to customers in March 1969. REDCOR was a small computer manufacturer headquartered in Canoga Park, California.

The software utilized a Computek terminal which was built around an OEM version of the Tektronix 4010 storage tube display. MCS' initial business strategy was to develop software such as ADAM and license it to other companies to market and sell to end users. By licensing the software, these companies would be required to provide training and technical support, relieving MCS of that responsibility. The first such licensee was Gerber Scientific which used ADAM to jump start its entry into the CAD marketplace with emphasis on the CAM portion of the process.

This was followed by a license to United Computing, also for resale to end users. United Computing was one of the early NC software firms with a batch product called UNIAPT. The intent was to use ADAM as the basis for providing an interactive version of the company's software. This eventually led to the initial development of the Unigraphics software package prior to United Computing being acquired by McDonnell Douglas Automation (McAuto). In addition to Gerber and United Computing, MCS also sold ADAM to some end users. Hanratty provided me with a copy of the ADAM menus printed in 1972 by Xerox in El Segundo, California (most likely the former Scientific Data Systems facility).

$S^3$ felt that ADAM was basically the same software as what it had acquired when it aquired ICS. As a result, $S^3$ initiated a lawsuit to prevent MCS from selling or licensing additional copies ADAM. MCS then countersued with its own lawsuit. It is possible that some of the transactions mentioned above actually happened after the lawsuit was filed.

The situation changed dramatically when $S^3$, which had started out as a technical consulting organization in San Diego, was acquired by a large retail organization which had little desire to develop CAD software. It was more interested in using the $S^3$ talent to develop retail transaction technology. The CAD development portion of the company was sold to Computervision which intended to use the $S^3$ technology as the basis for its CADDS-3 software. Albert, Devere and about a dozen other employees became Computervision employees with most of them staying in San Diego.

 

Along with the $S^3$ CAD operation, Computervision inherited the lawsuit against MCS. According to Albert, Computervision wanted to settle the suit as quickly as it could but it also wanted to minimize direct competition from MCS. Hanratty's position to this day is that ADAM was a separate package rewritten from the ground up. According to him, much of the ADAM code at MCS was written by John Tangney, the first full-time employee at the new company. When I first met Pat Hanratty in 1976, he was still furious over the $S^3$/Computervision lawsuit while in a recent interview he appears to have mellowed with time. The process of preparing for a trial involved taking a number of depositions. Working with his lawyer, Gar Schallenberger, Hanratty personally participated in these depositions, the objective of which was to prove that the MCS code was different than the ICS code.

According to Hanratty, Marty Allen, the president of Computervision, called him and offered to settle. Under an agreement finalized in 1973, Computervision licensed ADAM on a non-exclusive basis, agreed to pay Hanratty a $10,000 per month consulting fee for a year as well as MCS' legal fees. One of the issues over which there is still some confusion is whether or not the settlement limited the work MCS could do in the CAD area for a period of time. Hanratty used some of this time to obtain his Ph.D. in information and computer science at the University of California, Irvine.

**AD-2000 provides a substantial improvement over ADAM**

Subsequent to the agreement with Computervision, Hanratty moved MCS to Irvine, California. The user interface for ADAM consisted of 22 menus, each with five to 14 commands that covered the full range of three-dimensional design, drafting and NC. The software provided for 171 distinct command selections. Even at this early date, MCS claimed to be able to handle 5-axis machining which was a vital requirement in the aerospace industry. According to the menu listing, the package handled surfaces of revolution, tabulated cylinders, developable surfaces, ruled surfaces, and curved mesh surfaces. Both fixed and variable radius fillets were provided.

About the same time as the move to Irvine, Hanratty began the development of his next generation of mechanical design and manufacturing software, AD-2000. It had a vastly increased number of commands as compared to ADAM and was written for the new generation of 32-bit minicomputers that were starting to show up. The software still ran on 16-bit minicomputers, however, such as the DEC PDP-11.

AD-2000, which was initially released in 1976, had 42 different menus with a total of 405 commands. Major functional enhancements compared to ADAM included:

- An interactive software development capability called GRAPL (GRaphical Associated Programming Language later changed to GRaphical Application Programming Language) which enabled users to create specialized applications.
- Expanded surface geometry and an initial implementation of solid objects.
- Expanded drafting functionality.
- 2-D and 3-D analysis including mass properties.

Although AD-2000 presumed to provide extensive functional capabilities there was one problem - some of it simply did not work. Not all 405 commands were implemented, at least not in early releases. In some case, when a command was selected, a message would appear on the screen simply stating that the function was not available.

 

When questioned about this at the time, Hanratty's response was that the menu structure had been established to reflect planned development as well as existing capabilities. In later versions of its software MCS would be clearer about what was still under development.

There is little question but that it was AD-2000 that established Hanratty's reputation in the CAD industry. For the most part, MCS' focus continued to be licensing the software to other companies for resale. AD-2000 was licensed to Control Data Corporation which sold it as CD-3000, Kongsberg which sold it as CDM-300, Tektronix which sold it as DDN and Auto-trol Technology which initially repackaged it as GS-2000 and later as Series 7000. Apparently, Gerber and United Computing (perhaps after the latter was acquired by McAuto) also upgraded from ADAM to AD-2000. In addition, MCS licensed the software to NASA which made it available to certain contractors under its IPAD (Integrated Program for Aerospace Design) initiative. To a lesser extent, AD-2000 was sold to several large manufacturing companies for internal use including Caterpillar.

One area where MCS had success selling AD-2000 directly to end users was in the ship building industry. Newport News Shipbuilding, Bath Iron Works and Todd Shipyards all used the software for defining flame-cutter tool paths.

**Personal experience with AD-2000**

I was personally involved with two of the companies that licensed AD-2000, Tektronix and Auto-trol Technology. Tektronix signed a license agreement with MCS in 1978. The software was intended to be the core product in what initially was called the Dimension Series but later simply DDN for Design, Drafting and NC. My role was to manage the field sales and support for this activity. It took nearly a year to interface the MCS software with new Tektronix graphics hardware.

Hanratty felt that the work could have been accomplished in less time except that the Tektronix team under John Rowley seemed to want to do software development on the smallest system available. He very much liked the new write-through capability Tektronix had added to its 4014 storage tube displays. A basic characteristic of a storage tube display was that the entire image had to be redrawn when anything was deleted or moved. The write-through feature enabled the use of dynamic menus which could be changed without having to regenerate the entire image being displayed. It also permitted a limited amount of image dragging on the terminal.

Tektronix sold its first DDN system to Bethlehem Steel in June 1979. This was followed by a large order from Reynolds Metals and a smaller order from Pratt & Whitney. Other accounts included Eastman Kodak and Aerojet General. One of the major problems Tektronix had selling its version of AD-2000 was that it started to run into competition directly from MCS. The Tektronix marketing personnel were never able to articulate why its version of the software was preferable to the MCS version.

Just as this business was starting to gain some real momentum, Tektronix decided in November 1979 to get out of the CAD systems business. While Hanratty felt that this was a shortsighted move on the company's part, he also felt that he was well treated by Tektronix when it negotiated a settlement with him. It is not clear what happened to most of the installations Tektronix had sold - Reynolds Metal was very upset and probably received some form of compensation from Tektronix while Pratt & Whitney continued using Hanratty software, dealing directly with MCS. In a January 1987 article on MCS in *The Anderson Report*, Pratt & Whitney was reported to have 150 seats of MCS software installed on a variety of IBM mainframes using IBM 5080 displays at its West Palm Beach, Florida plant.[1] This could have been Tektronix business if the company had persisted in the CAD market.

The experience at Auto-trol was somewhat different. That company signed a license agreement with MCS for AD-2000 in mid-1979. As described in Chapter 9, Auto-trol's primary system at the time was called the AD/380. It was built around a Sperry Univac V77-600 minicomputer and used Tektronix storage tube graphic terminals. In late 1979 the company introduced an advanced graphics workstation called the CC-80 which incorporated a Texas Instrument microprocessor as a local controller. An AD/380 system could support up to 12 CC-80 workstations. Auto-trol had tried unsuccessfully to develop its own mechanical software for the AD/380 called GS-200.

Upon licensing AD-2000 they dropped the GS-200 project and began to port the MCS software to the AD/380 and the CC-80. It took about six months before the company had deliverable software which was called GS-2000. That was about the point in time when I joined Auto-trol as director of product planning although in that role I had little to do with the development and marketing of GS-2000. I was aware that the developers had serious problems keeping their modifications in sync with new releases of AD-2000 coming from MCS. Eventually it reached the point where Auto-trol felt that a fully paid up license with no further enhancements was the preferable way to go. They paid MCS $1 million in the latter part of 1980 and MCS gave the company its latest AD-2000 source code and terminated all future royalty payments.

It is hard to tell if that was a good move or not since MCS was in the process of developing a new, more stable version of its software called ANVIL-4000. Auto-trol continued to sell its version of the software for the next 15 years. It was ported to the Digital VAX 11/780 and eventually to Apollo, Sun and Digital workstations under the Series 7000 brand. Over time, much of the original AD-2000 code was replaced with new software developed internally by Auto-trol personnel although it never became a major source of revenue for the company. Starting in 1990, Auto-trol attempted unsuccessfully to develop a new mechanical design package from scratch.

**MCS becomes a real software company**

Until 1980 MCS and Hanratty focused on developing advanced mechanical design and manufacturing software that would either be resold by turnkey systems companies or MCS would sell it to large organization that had the technical resources to tailor the package to their specific needs. In particular, MCS software was fairly widely used by the nuclear weapons community with installation at Los Alamos, Sandia Laboratory, etc. They liked AD-2000 and the capabilities of subsequent MCS software to machine complex surfaces and were willing to put up with the software's idiosyncrasies.

With the introduction of ANVIL-4000 in 1981, that business strategy changed and MCS became a more typical software firm selling directly to end users. While the company still licensed its software to companies such as Harris Corporation and Graphtec for resale, the major focus shifted to developing a direct sales capability.

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[1] *The Anderson Report*, January, 1987, Pg. 3

 

The name ANVIL came from Hanratty's idea that MCS was the "computersmith," providing users with tool kits. An anvil is an important tool for a blacksmith so it was not a huge leap to call the software ANVIL. As AD-2000 had added many capabilities to ADAM, ANVIL-4000 was an equally significant upgrade of the company's AD-2000 software. ANVIL-4000 contained 80 distinctly different menus with approximately 1,080 commands as compared to 42 menus and 405 commands in AD-2000. This time, MCS acknowledged that some of the commands such as dimensions in feet and inches, data graphing, a finite element interface to ANSYS, and piping design were still in development. When ANVIL-5000 came out around in 1986, some of these, such as feet and inch dimensions, had been implemented while others including piping design never made it into the package.

Two differences from AD-2000 were that ANVIL-4000 was more standards oriented and it had the capability to support two-byte characters. The latter feature made it feasible to support Asian languages such as Japanese and Chinese. One problem users had to adapt to was that the menu structure changed significantly between AD-2000 and ANVIL-4000, requiring users to learn where old commands were on the new menus as well as learn the new functionality. Even on menus for creating simple geometry such as points and lines, some of the commands either were changed or were in subordinate menus. In general, most of the added capabilities extended existing functions that were already in AD-2000 rather than creating entirely new areas of design and drafting.

According to the August 1982 issue of *The Anderson Report*, ANVIL-4000 was written entirely in FORTRAN and was intended to run on computers with a word size of 24 bits or larger. In some situations MCS also used the ANVIL-4000L nomenclature for this package. While the article did not mention which computer systems the software was currently available on, it did list eight different manufacturers whose terminals were supported: Tektronix, Megatek, Lexidata, Ramtek, Imlac, Genisco, Vector Automation and Vector General.[2]

ANVIL-4000L was packaged in five different modules which could be purchased in a variety of combinations:

- A basic package for control and viewing of geometry ($31,000)
- Drafting ($15,000)
- Extended geometry ($28,000)
- Numerical control ($26,000)
- Analysis ($7,000).

It is assumed that MCS probably offered discounts from these individual prices if a company wanted to buy the complete suite or wanted multiple copies. While $107,000 sounds high by today's standards, it was actually fairly reasonable in 1982. An IBM mainframe could easily support 12 or more terminals, bringing the price of the software down to less than $10,000 per seat. The software could also be leased from MCS for about 5% of list price per month. It is not clear what the company charged for software maintenance and whether the lease prices included maintenance and support.

MCS also offered a two-dimension version of the software called ANVIL-3000D which was intended for mechanical drafting applications. This software supported a wide range of international drafting standards and included capabilities for users to create their

[2] *The Anderson Report*, August, 1982, Pg. 3

 

own standards. In addition to orthographic drawings, ANVIL-3000D could also be used to create isometric drawings. According to *The Anderson Report* article, this package supported IGES, a fairly new interoperability standard at the time, as well as the ability to exchange files with ANVIL-4000L.

The ANVIL-3000D software was only available on a monthly lease basis, $1,750 for one or two terminals on up to $4,000 per month for 37 or more terminals. One of the more interesting features of ANVIL-3000D was a computer-aided instruction capability that the company felt would significantly reduce the time needed to learn the software. This would continue to be a training theme at MCS in the future.

**MCS becomes a turnkey systems vendor**

In 1982, MCS made its first attempt to sell packaged systems and terminals configured specially for MCS software. One product was a turnkey system called ANVIL-3000. It was based on a Hewlett-Packard 1000F minicomputer, a high-resolution raster display and the ANVIL-3000D software. It was priced around $90,000 with a single display terminal and $105,000 with two. In addition, MCS offered two graphics terminals specifically configured for its software. The ANVIL-1200 IID system was based on the Genisco G-1000 monochromatic raster display with 1,000-line resolution. It incorporated a Zilog Z8001 microprocessor with 320KB of memory and supported local manipulation features such as zooming, panning, dragging, rotating, cursor tracking, and erasing as well as digitizer support. Prices for this unit started at $15,750. It had initially been introduced at $18,750 but, apparently, that was not a very competitive price.

The second terminal was the ANVIL-1600 IID which was based on an Imlac DYNAGRAPHICS II stroke refresh display and an Intel 8086 microprocessor with 192 KB of memory. Resolution was 2048 by 2048. In both cases, the user still needed to provide a host computer system. By using microprocessors in the terminal devices some of the interactive functionality of the ANVIL software was implemented on the terminal, improving user performance. Other vendors such as Auto-trol Technology and Computervision were taking similar steps at that time with their terminal hardware.

To the best of my knowledge, MCS did not sell very much specialized hardware. The business was predominately software. *The Anderson Report* estimated that in 1982 MCS was doing about $5 million in annual revenue with all sales being handled out of its Irvine headquarters. Daratech reported in its *1983 Survey and Buyers Guide* that MCS had agreed to sell Impell Corporation 21% of its stock for $5 million.[3]

In mid-1983, MCS announced that the ANVIL-1200 IID terminal would henceforth be sold directly by Genisco Computers with a new price of $12,000. In September 1983, the MCS organization expanded with Tom Yarker promoted to vice president of technology, Ross Stoutenborough promoted to director of technical development and Morton Chonoles hired as national sales manager.

Starting around this time, MCS negotiated agreements with Digital Equipment, Prime Computer and Data General for these companies to resell ANVIL-4000. To the best of my knowledge, only Digital made any significant effort to build the necessary staff and aggressively promote the MCS software. In May 1984, Hewlett-Packard joined this list with an agreement to provide ANVIL-4000 on HP 9000 series computers.

[3] Daratech Corporation, *1983 Survey and Buyers Guide,* Pg. 18-205

In May 1984, HP acquired a 10% interest in MCS. According to Hanratty, this upset the other computer manufacturers who were selling his software and they ceased doing so. Hanratty soon became concerned because at the same time one HP group was acquiring an interest in MCS, another group within HP was in the process of acquiring a software company in Germany. This latter deal led to HP products such as ME-10 and ME-30, the establishment of that company's Mechanical Engineering Division and its eventual spin off as CoCreate.

**Leaping into the world of personal computers**

In late 1984, MCS introduced ANVIL-1000MD, a two-dimensional drafting subset of ANVIL-4000 implemented on an IBM PC/AT. The original plan was for IBM to use the package during the launch of the PC/AT and to subsequently market the software. A complete configuration including a PC/AT with 640KB of memory, a 20MB hard disk, a floppy disk, an 80287 math coprocessor, the IBM Professional Graphics Controller/Color Graphics Display, a B-size plotter and the software sold for $15,885. The software alone sold for $2,995. Although ANVIL-1000MD was technically well done, according to Hanratty it was error free when it was released, it ran into political problems at IBM.

For a number of years IBM had been selling CADAM, a mechanical drafting package developed by Lockheed which ran on the company's mainframe computers. Apparently, the thought of having IBM's upstart PC division selling a low cost alternative upset the mainframe part of the company and they lobbied successfully to stop IBM from selling ANVIL-1000MD. Three days before the formal launch was scheduled, IBM cancelled its contract with MCS even though Hanratty had prepared 10,000 copies of the software in anticipation of expected orders from IBM.

With IBM out of the picture, Tom Yarker, who had been instrumental in the development of ANVIL-1000MD, asked Hanratty if he could take over the marketing and sales of the package. Yarker set up a company called Integrated Design Consultants (IDC) and was fairly successful selling ANVIL-1000MD. According to Hanratty there were probably 5,000 copies still in use in 2000 and MCS frequently received calls from users who were interested in upgrading to ANVIL EXPRESS which is described below.

While the $2,995 price was more than what other PC-class drafting software from vendors such as Autodesk sold for at the time, it had more extensive capabilities. In addition, it was far less expensive than drafting software available from mainstream CAD vendors. Sales into the MCS customer base were handicapped by the fact that an interface between ANVIL-1000MD on one hand and ANVIL-4000 and ANVIL-3000 on the other hand, did not exist when the product was first introduced. Also, IDC was slow to develop an effective distribution channel for ANVIL-1000MD that was capable of competing effectively with Autodesk. MCS would come back to the PC as its primary platform, however, in later years. See Figure 15.4.

In early 1985, MCS announced that, working with Hewlett-Packard, it had initiated a development program to embed much of the ANVIL-4000 software code in silicon. Since many graphics functions that had initially been performed in software were becoming incorporated into display hardware, doing the same with CAD functions seem like a logical extension of what was going on in the computer industry.

 

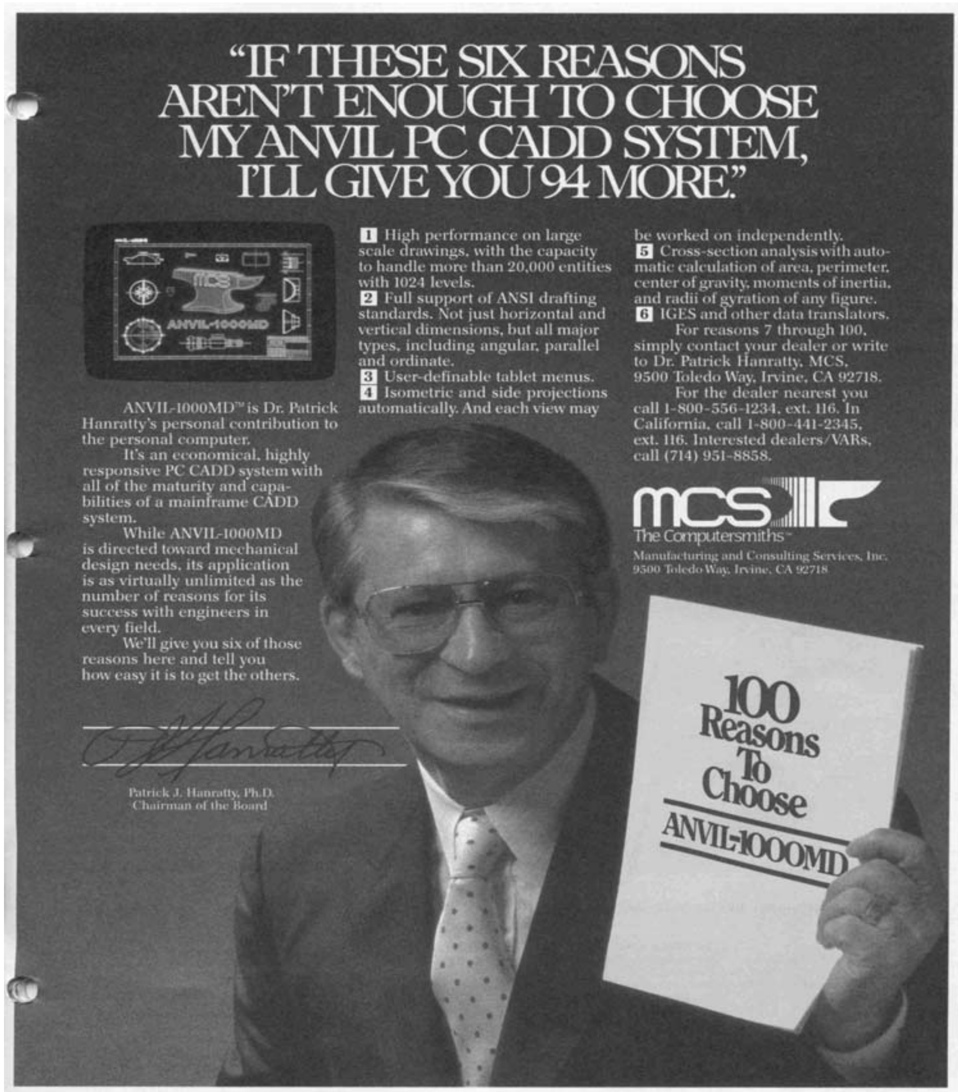


Figure 15.4

Pat Hanratty and advertisement for ANVIL-1000MD from *CAD/CIM Alert CAD/CAM/CAE Product News Supplement* - March/April 1986

The plan was to have key ANVIL routines available by late 1985 and the entire million lines of ANVIL code converted in two to three years. Hanratty felt that this could speed up complex operations such as those involved in solids modeling by a factor of 100 to 200. It never happened. My expectation is that it was a combination of cost and technical challenges that prevented this from occurring. Also, around the same time, the computational performance of computers was starting to improve at an accelerating rate.

**MCS software matures with introduction of ANVIL-5000**

The next product in the ANVIL family was ANVIL-5000 launched in January 1986. It was targeted at UNIX workstations such as those offered by Hewlett-Packard, Apollo, and Sun Microsystems as well as legacy computer systems sold by Digital and

 

IBM. As with ANVIL-4000, ANVIL-5000 was also implemented to run on IBM mainframes at the request of major customers such as Martin Marietta and Pratt & Whitney. MCS continued to support IBM mainframes for a number of years until the cost of doing so for a fairly limited market became prohibitive.

ANVIL-5000 implemented a consistent user interface across applications as well as a common double-precision database for wireframe, surface and solid models and all the applications that used this data. In this regard, it was several years ahead of Parametric Technology. The new software had 335 distinct menus which supported over 2,000 commands.

One of the more significant additions was a new optional solids modeling module called OMNISOLIDS which had a list price of $25,000. The result was one of the first CAD/CAM packages that tightly integrated wireframe, surfaces and solids. Some of the company's competitors would not reach this point with their software for another five years or more. In addition, the product's geometric design, drafting, and NC control functions had expanded significantly from those available in ANVIL-4000. These new developments helped MCS win a significant contract to provide design software to 12 Department of Energy sites in the fall of 1986.

According to an in-depth profile in the January 1987 issue of *The Anderson Report*, ANVIL-5000 was available in twelve different combinations of six basic modules: 3-D Design and Drafting, Surface Modeling, OMNISOLIDS, OMNIFEM, Numerical Control Machining and 5-axis Numerical Control Machining. Separating 5-axis machining from basic NC control was a recognition that this capability was far more complex than standard machining operations.[4]

The double-word database meant that parts could be designed and machined to 15 decimal digits of precision. Here also, MCS was several years ahead of most of its competition. As mentioned earlier, the ANVIL software was widely installed within the nuclear weapons community mainly for its ability to design and machine accurate weapon components. While ANVIL-5000 excelled as a part design and manufacturing tool, it was not particularly strong in regards to the design of complex assemblies, but neither were its competitors at the time.

Pricing for ANVIL-5000 ranged from $5,000 per seat in a 12-seat configuration running the basic design and drafting module to $19,000 per seat for the complete suite of software on the same 12-seat configuration. There were several problems associated with the introduction of ANVIL-5000. As with the transition from AD-2000 to ANVIL-4000, ANVIL-5000 users had to learn new ways to do some of the same tasks they had been doing previously with ANVIL-4000. In addition, there was no software initially available to move ANVIL-4000 data to ANVIL-5000. Some users resorted to using IGES for accomplishing this task. Also, the broad range of hardware MCS was attempting to support may well have overtaxed the company's development staff.

Meanwhile, MCS, in conjunction with IDC, was continuing to market the drafting-centric PC packaged it had introduced several years earlier, ANVIL-1000MD. It now supported a broad range of tablets for data and command entry as well more than 30 different models of plotters. Working with Kurzweil Applied Intelligence of Waltham, Massachusetts, MCS had implemented a voice actuation capability for ANVIL-1000MD in the spring of 1986. Several other vendors including Calma were experimenting with

[4] *The Anderson Report*, January, 1987, Pg. 3

voice actuation at the same time. In general, the user community rejected this technique of entering commands and data and it has never caught on for engineering design and drafting applications. MCS now had software that could exchange data directly between ANVIL-1000MD and the company's high-end packages.

According to *The Anderson Report*, MCS had about 100 employees and was doing about $10 million in annual revenue as of the beginning of 1987. The newsletter also estimated that the company had sold approximately 5,000 seats of ANVIL-4000 and ANVIL-5000 and perhaps 3,000 ANVIL-1000MD systems. About 60% of its high-end software was installed on Digital VAX computers with much of the rest on UNIX workstations. Apollo was the fastest growing segment of its market. Many of these customers would continue using MCS software well into the following decade and even beyond. This was particularly true for companies that designed parts that used injection molding for their manufacture. ANVIL-5000 proved to be an excellent package for machining molds for producing these parts.

At this point, MCS told *The Anderson Report* that it was ready to greatly expand its sales activity by opening four to six new sales offices and add about 30 direct sales people. For the most part, this never happened. The company also planned to become more of a system integrator by reselling workstations from Apollo and Sun. The December 1987 issue of *The Anderson Report* reported that MCS had signed $6 million OEM deals with both vendors.[5] As best as I can tell, this did not become a major element of the company's business.

In its January 1987 article, *The Anderson Report* concluded:

> "Pat Hanratty is a brilliant technologist and a natural salesman par excellence. There is little doubt that Hanratty is the dominant and controlling force at MCS. With this highly centralized control the company can respond quickly to market changes and make efficient use of its R&D resources. The bad news is the difficulty of doubling or tripling in size without changing the company structure. We believe MCS is ideally positioned to capitalize on the new era in CAD. They sell software only, that runs on all the popular platforms. Their product is powerful and more complete than previous MCS products. They have a PC strategy in place. We sense a reasonable satisfied and loyal user base from a user group meeting we attended. With these things in place MCS could be one of the fastest growing companies in CAD/CAM. Whether they choose to go for it remains to be seen."[6]

A good example of the difference between developing a good product and adequately marketing it would be MCS' experience with Anvil 1000. In June 1987, *Computer Aided Design Report* reviewed the results of a evaluation the publication had done of several leading PC CAD packages. Anvil 1000 came out as the top rated package in its class. "Anvil 1000 is still the best PC CAD package for mechanical drafting we've seen. It is priced fairly and should work even better on IBM's new PS/2 and other high-performance personal computers."[7]

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[5] *The Anderson Report*, December, 1987, Pg. 7
[6] *The Anderson Report*, January, 1987, Pg. 5
[7] *Computer Aided Design Report*, June 1987, Pg. 1

1987 and 1988 represent a high point in the history of MCS. The business was sufficiently profitable that Hanratty was able to build a 7,000 square foot home in the Luguna Hills section of Orange County. In an attempt to generate incremental revenue, MCS signed an agreement with Tektronix in early 1989 to resell Tektronix 4300 workstations with ANVIL-5000 software. Customers could evaluate the combined package for 90 days by paying just 2.7% per month of the hardware cost. The software was tossed in free during the evaluation. The major flaw in this strategy was that the 4300 never made much of an impression on the CAD/CAM user community and it is doubtful if very many prospects took MCS up on this offer.

One significant development that occurred during the next several years was the porting of ANVIL-5000 to the PC platform, providing customers with similar capability to what they could obtain on UNIX platforms. The 80386 version of design and drafting software sold for $3,995. That was about the same as what a new generation of mid-range vendors led by SolidWorks and Solid Edge (Intergraph) would charge in the mid-1990s. One result of porting ANVIL-5000 to the PC was that 2 ½ D ANVIL-1000MD became somewhat redundant although it did continue to be sold with a suggested retail price of $2,995.

**Relocating to Arizona and continuing focus on ANVIL-5000**

By early 1990, Hanratty was becoming quite frustrated with the business climate in southern California as well as the air pollution it was necessary to live with. Initially, he thought about relocating the company to some land he owned in the Sierra Nevada mountains of California. This land had been acquired as a result of his earlier settlement with Tektronix. Most of the MCS staff indicated that they were not interested in that idea so Hanratty went to Plan B which was to move the company to Scottsdale, Arizona where it has been since the summer of 1990. About 40% of the Irvine staff made the move to Arizona with Hanratty.

Two of those were Hanratty's sons Brian and Scott. Brian Hanratty joined MCS in 1976 as a system analyst and eventually became senior vice president and second in command with direct responsibility for software development. Brian has a masters degree in computer science from West Coast University in Los Angeles. Scott Hanratty joined MCS in 1981, responsible for corporate marketing. In the 1990s he was vice president, marketing and corporate operations. Scott has a BS degree in business administration from Pepperdine University in Malibu, California. The move to Arizona also encouraged John Tangney to rejoin the company. He had quit in 1977 to escape the smog and overcrowding of southern California and had joined Tektronix in Oregon.

The next several years were fairly quiet with MCS making few significant announcements. Between August 1990 and August 1993, *The Anderson Report* had just one brief news item concerning MCS. It reported in October 1991 that MCS had signed an agreement with Silicon Graphics to bundle ANVIL-5000 with SGI's Indigo UNIX workstation and sell the combined package for just $19,910. It is assumed that this included just the basic ANVIL-5000 design and drafting module. The hardware and software bundle was to be sold by both MCS and SGI as well as their reseller organizations.[8] This was similar to the deal MCS had with Tektronix in 1989. Neither

[8] *The Anderson Report*, October, 1991, Pg. 3

 

made much headway in expanding the company's business. One indication that MCS was loosing some of its earlier sales momentum was when Sandia National Laboratories, a long time AD-2000 and ANVIL user, awarded PTC an order for 600 copies of Pro/ENGINEER in July, 1992.

While the company might have been quiet on the PR and marketing fronts, it was continuing to enhance ANVIL-5000. Release 3.0 came out in early 1993 with new capabilities such as a more friendly user interface based on the MOTIF standard, faster performance and new NC capabilities. Perhaps the most significant enhancement the company announced at this time was AIM - the ANVIL Intelligent Modeler. It incorporated parametric techniques that facilitated rapid changes of part designs as well the creation of wireframe and surface models. The unit price for AIM was $10,000 for the UNIX workstation version and $6,700 for the PC version. AIM was intended to replace the earlier OMNISOLIDS solids module. Unfortunately, it never lived up to expectations.

The NC software incorporated new electrical discharge machining (EDM) capabilities as well as enhanced multi-surface machining. With the introduction of Release 3.0, MCS also announced that the final two ANVIL-5000 modules, Solids Modeling and 5-Axis Machining, had been ported to DOS PCs. Later in 1993, MCS broadened its product line with a sheet metal package it had acquired from Lennox International of Dallas, Texas, an ANVIL-5000 user that manufactured heating and air conditioning equipment. In April 1994, MCS introduced ANVIL-5000 Release 5.0 including ANVIL-Vision for photorealistic rendering based on LightWorks software and the Lennox sheet metal module.

Indicative of the problems editors had following what was available and what was planned for later delivery, MCS announced AIM a second time in March 1994 at the National Design Engineering Show in Chicago. Then, several months later we received another press release announcing the availability of the EDM software which had originally been included with the release 3.0 announcement.

*Engineering Automation Report* was started in March 1992 and acquired *The Anderson Report* in October 1995. An indication of the extent that MCS was out touch with the media during the early 1990s is that *EAReport* only mentioned MCS briefly in the context of the company showing new releases of ANVIL-5000 at several tradeshows until it did an in-depth profile in May 1995.[9]

Likewise, *The CAD Rating Guide* in its 1991 Second Edition and its 1993 Third Edition[10] have quite cryptic descriptions of MCS and the company's products. Since the information in the *Guide* was mostly provided by the vendors, it appears that for several years, the company simply did not pay much attention to the media. Its focus tended to be on the company's customer base. During these years anywhere from 125 to 500 people would show up for MCS' annual user conference.

The May 1995 MCS profile in *EAReport* seemed to coincide with an upswing in the company's marketing and promotion activity. It reviewed the company's earlier activities as described above. Much of the article described the current state of ANVIL-5000 with emphasis on AIM. In addition to the earlier described AIM, a two-dimensional

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[9] *Engineering Automation Report*, May 1995, Pg. 6
[10] Holtz, Bradley W., *The CAD Rating Guide, 3rd Edition*, 1993, Pg. 182

version was now available that facilitated the creation of parametric drawings. The company described it as “drafting software on steroids.”

GRAPL-IV was now included as part of the basic package while a new option, Extended GRAPL-IV, enabled users to directly access the ANVIL database. A viewing and redlining module called Design Review had also been added to the ANVIL suite. MCS’ software prices as of mid-1995 are shown in the following table.

**ANVIL-5000 Prices**

| Module | Workstation Price | PC Price |
|---|---|---|
| Design/Drafting | $12,000 | $8,000 |
| Extended Geometry | $8,000 | $5,300 |
| 2 ½-Axis NC | $4,000 | $2,700 |
| 3-Axis NC | $2,000 | $1,300 |
| 5-Axis NC | $4,000 | $2,700 |
| AIM | $10,000 | $6,700 |
| 2-D AIM | $5,000 | $3,000 |
| Design Review | $1,500 | $1,500 |
| ANVIL-Vision | $4,000 | $3,000 |

In general these prices were somewhat high when compared to other workstation solutions such as Pro/ENGINEER and the PC prices were quite high when compared to new mid-range solutions such as SolidWorks although, at this point in time, ANVIL-5000 had far more capability than the early releases of SolidWorks.

*EAReport* summed up its review of MCS with the following:

> “Having known Pat Hanratty for nearly 20 years, our view may be a little biased. He always seems to be several steps ahead of where the rest of the industry's thinking is at any given moment. For many years, we watched MCS almost but not quite hit stride. It appears that the latter part of this decade may be its time in the sun. The company consists of a tightly knit team of dedicated individuals who want to show the world that substance is what counts in the long run.
>
> ANVIL-5000 is a serious product that deserves more attention than it has received in recent years. While the product line is not as broad as that offered by some vendors and the workstations prices are somewhat expensive, it is quality software. If your business is designing and manufacturing complex parts, we recommend that you take a look at the new ANVIL-5000 Release 5.”[11]

The depth of data in the1994 Fourth Edition of *The CAD Rating Guide* was more extensive than in earlier editions reflecting an increased interest by MCS in getting the message about its products. The 1997 Fifth Edition reported that prices for ANVIL-5000,

[11] *Engineering Automation Report*, May 1995, Pg. 6

which was now at Release 6.0, had come down substantially. A complete CAD/CAM solution with 5-axis NC could be purchased for $9,500, which was comparable to what SolidWorks with a good third-party NC package cost.[12]

**Re-energizing MCS with the introduction of ANVIL-Express**

By early 1997, MCS was having problems matching the technical development resources and marketing strength of the major CAD players such as Dassault Systemes, Unigraphics Solutions, PTC and SDRC. Likewise, a new generation of mid-range players such as SolidWorks and the Solid Edge business unit at Intergraph were starting to create increased competitive pressure on the company. MCS had annual revenues in the $20 million range and Hanratty had stepped back from hands-on day-to-day technical management of the company.

One area where MCS was particularly lagging was in the use of solids modeling. The company had taken several shots at delivering this technology such as OMNISOLIDIDS and AIM, but simply did not have the resources to develop a complete solids capability by itself. In early 1997, the company licensed the Parasolid kernel and the Parasolid software development toolkit from EDS' Unigraphics Solutions. The plan was to use the Parasolid kernel for the company's next generation solid modeler. The new solid modeler was intended to form the basis for MCS' ANVIL EXPRESS, a fairly substantial overhaul of the company's flagship ANVIL-5000 software. John Tangney was now director of technical development and was leading the charge.

The objective was to provide an integrated design, drafting and NC package at close to the cost of the new mid-range packages, all of which required third-party packages to handle NC operations. ANVIL EXPRESS differed from ANVIL-5000 in a number of significant ways.

- Although ANVIL EXPRESS utilized many ANVIL-5000 routines, much of the code had been rewritten in C++.
- Whereas prior MCS software had been implemented to run on a wide range of computer systems, ANVIL EXPRESS was aimed specifically at the PC market using several different versions of Windows.
- The new software would maintain bi-directional compatibility with earlier MCS software products.
- ANVIL-5000 had a massive number of discrete menus and individual commands. This was greatly simplified with ANVIL EXPRESS, partially through the use of the Windows user interface.
- Prices were far more competitive - basic drafting started at $2,995, surface modeling at $3,995, solids modeling at $5,995 and design, drafting and 3-axis NC at $8,995.
- The new software included multi-media training and tutorials which could be tailored the user's level of expertise.
- New technology developed personally by Pat Hanratty called AUTOSNAP 3D enabled users to convert 2D drawings into 3D solid models.

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[12] Holtz, Bradley W., *The CAD Rating Guide, 4th Edition*, 1994, Pg. 244 and *The CAD Rating Guide, 5th Edition*, 1997, Pg. 245

The latter two features were particularly significant. Unfortunately, AUTOSNAP 3D was still more of a research project than production code in 1997. In fact, five years later, Hanratty was still working on refining this software.

Prior to its release in the fall of 1997, a significant change was made to ANVIL EXPRESS. Rather than complete the development of a solid modeler built around Parasolid, the company decide instead to OEM and resell the SolidWorks package from SolidWorks Corporation, a division of Dassault Systemes. SolidWorks also used Parasolid. Hanratty's statement to me at the time was that the development of a Parasolid-based solid modeler exceeded the R&D resources of MCS.

MCS tried to build some interest in AUTOSNAP 3D by licensing the software to the Solid Edge business unit of Unigraphics Solutions (acquired from Intergraph in early 1998) which planned to sell it as a $495 option. It looked good when demonstrated at a Solid Edge user conference in 2000 but Solid Edge's technical personnel concluded that it didn't handle a sufficiently broad range of cases. As a consequence, the software was never actually marketed by Solid Edge.

Over a four year span MCS shipped several additional ANVIL EXPRESS releases but sales of this product never lived up to early expectations. While some ANVIL-5000 users switched to ANVIL EXPRESS or simply continued using ANVIL-5000, many others switched to competitive products. As the company's revenues began dropping, financial problems began to spring up. The critical moment came in 2001 when SolidWorks demanded payment on past due invoices for copies of SolidWorks MCS had purchased for resale. The money was not available and SolidWorks cancelled the company's resale agreement. This basically shut down the sale of new ANVIL EXPRESS licenses to a trickle and the company laid off most of its employees.

By 2002 MCS was just a shell of what it once was. There were a few employees providing support to a core group of loyal customers and Pat Hanratty was still programming away on the latest version of AUTOSNAP 3D.

# Chapter 16

# Parametric Technology

Parametric Technology Corporation was founded in May 1985 by Dr. Samuel P. Geisberg as SPG Consulting Corporation. Born in St. Petersburg, Russia in 1936, Geisberg earned a Ph.D. in mathematics and became a professor of mathematics at Leningrad University. He emigrated to the United States in 1974 with his 11-year-old son. His wife, Mira, and their six-year-old daughter had to stay behind because of her work on several defense related projects. It would be several years before she was able to join him in the United States.

Geisberg first worked for Computervision and then for Applicon. At both companies, particularly at Applicon, he proposed developing a radically new approach for CAD software, one that would be based on solid geometry and would use feature-based parametric techniques for defining parts and assemblies. When neither company agreed to fund his proposals, he decided to start a new company to produce the advanced design software he was contemplating.

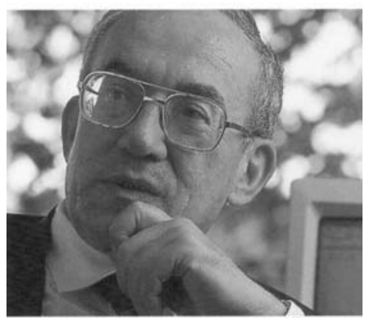

Figure 16.1
Dr. Samuel P. Geisberg

The reader should not assume that Geisberg was the only software developer working on these techniques. Some aspects of the fundamental ideas behind what eventually became Pro/ENGINEER were already being implemented by Matra Datavision, Intergraph and others. What separated PTC from these other vendors was the overall completeness of Pro/ENGINEER and its single data model concept for all design, analysis and manufacturing applications although it would be some time before this became clear to users and competitors.

PTC got started when Sam's brother Valdimir, who had emigrated from Russia in 1980 and had also worked at Computervision, suggested that Sam speak to an attorney named Noel Pasternak about setting up and financing a new company. Pasternak rounded up $150,000 in seed funding that enabled Geisberg to start work on the prototype for Pro/ENGINEER. Geisberg insisted that Pasternak put up $25,000 of the money personally. The company was incorporated in May, 1985. In the August 29, 1993 issue of the *Boston Globe*, Pasternak was quoted as saying, "I think having come from Russia, Sam wasn't sure who his friends were and who his allies were …. He felt that if I had some money up, I would fight even harder for him."[1] More than 20 years later, Pasternak is the company's non-executive chairman of the board.

In all, about $750,000 in initial seed funding was raised from Adage, Charles River Ventures and others. The key step was building an organization that could complete the development of Geisberg's software ideas and bring the resulting product to market. The bulk of the early development work was done by Geisberg and four or five associates. Mike Payne, who had spent a number of years at Prime Computer as director of CAD/CAM research and development, joined PTC in March 1986 and a month later became vice president of development.

Being basically a mathematician and software developer, Geisberg and his backers recognized fairly quickly that they needed someone with more management experience to run the company on a day-to-day basis and as a consequence the company hired Steven C. Walske as president and chief executive officer in December 1986. Walske received an MBA from Harvard Business School in 1978 and was CFO of Computer Corporation of America prior to joining PTC. Under his leadership the company grew from a cold start to over $1 billion in revenue 12 years later.

After Walske joined the company, Geisberg became executive vice president of research and development. Six months later, Dick Harrison was hired as vice president of sales and the company's name was changed to Parametric Technology Corporation. Harrison had previously been a sales executive with Celerity Computing and Prime Computer.

In mid-1987 the company raised an additional $3.6 million in venture capital funding from Charles River Ventures[2] and others and began to prepare Pro/ENGINEER for launch later that year. About the same time, the company began demonstrating an early version of the software to the press. Publications including *CAD/CIM Alert* and *The Anderson Report* were suitably impressed. While most CAD software vendors had a preferred computer platform on which the company developed software and then ported the software to other platforms, PTC took the approach of developing its software on multiple platforms at the same time. Initially, this included workstations from Sun, DEC, Apollo, SGI and NEC. Except for using VMS on the DEC systems, PTC focused on UNIX as its primary operating system. While there was talk of a version that would run on an IBM System/2 PC or an Apple Macintosh, the PC version would have to wait for Microsoft's release of Windows NT in 1993.

According to Geisberg at the time:

> "The goal is to create a system that would be flexible enough to encourage the engineer to easily consider a variety of designs. And the cost of making design changes ought to be as close to zero as possible. In addition, the traditional CAD/CAM software of the time unrealistically restricted low-cost changes to only the very front end of the design-engineering process."[3]

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[1] *Boston Globe*, August 29, 1993

[2] One of the general partners at Charles River Ventures was Don Feddersen, a former president and CEO of Applicon who was a director at PTC for a number of years.

[3] Teresko, John, *Industry Week*, December 20, 1993

Prior to Pro/ENGINEER's formal release, the expected base price for the software was $12,500. The entire suite consisted of about ten different modules including basic sketching, feature-based modeling, drawing generation, assembly modeling, surface geometry, data management, etc. Eventually these modules, along with many other capabilities, would become part of the basic Pro/ENGINEER product. Although all modeling was done with solid geometry, users could work with either wireframe or hidden-line images as well as shaded images. Most early users worked predominately with wireframe images due to the performance of contemporary workstations.[4]

Beta testing of Pro/ENGINEER began in September 1987 with the first public demonstrations taking place at AUTOFACT in Detroit, Michigan in November 1987. Commercial shipments began in January 1988. The price for the basic software which consisted of parametric geometry creation, drawing generation, assembly modeling, and IGES 3.0 was reduced to $9,500. The company's initial distribution plan was to use dealers (Value Added Resellers or VARs) and OEM resellers. At product introduction, PTC had lined up four domestic dealers and two in Japan. The plan was to have 50 dealers by the end of 1988. It was not long before the company incurred significant conflict between these outside firms and its internal direct sales force.

**Functional Description of Pro/ENGINEER**

Although individual aspects of Pro/ENGINEER had appeared earlier in competitive software products, this product's introduction in late 1987 was the first time these capabilities had been grouped together in a single software suite together with a fairly straightforward user interface. Two basic principals drove the early development of Pro/ENGINEER. One was the use of parametric, feature-based solids modeling while the other was the concept that all applications in this software suite would use a common data structure.

While competitive products such as Computervision's CADDS 4X and McAuto's Unigraphics II were fundamentally wireframe based with solids added as an extra capability, Pro/ENGINEER was implemented from the start as a solids-based system. Everything was done with double-precision solid geometry and NURBS surfaces.

To create a model, the user typically started by creating a profile of the object. This shape was then converted into a solid model by translating it through space or revolving it around a centerline. Additional geometry could be added or subtracted from the base model. Some of the geometry was in the form of features such as holes, bosses, ribs, etc.

A key characteristic of Pro/ENGINEER was that as the model was created, the software recorded each step the operator took. This was referred to as a "history tree." The software also recoded geometric aspects of the model such as whether two surfaces were parallel or the fact that a hole was a specified distance from the edge of the part. Each dimension used to define the part was also recorded. If the user placed a through hole in a block and the thickness of the block was later increased,

[4] *CAD/CIM Alert*, July 1987, Pg. 11 and *The Anderson Report*, July 1987, Pg. 3

 

the length of the hole would increase proportionately. With older solid modelers, the user would have been left with the hole ending inside the block.

One aspect of Pro/ENGINEER that was an early strength but would later be a problem was the fact that the model was always fully constrained. That meant that there were no redundant constraints nor could the model lack any information that fully defined its geometry. If a critical dimension or constraint was missing, the software would alert the user of this fact and would not proceed until the necessary information was provided.

If the user decided to change a dimension, the software would use the saved history tree to regenerate the model. For small models, this was nearly instantaneous but as models became larger, the time increased significantly. These changes were incorporated into the history tree so that as more and more changes were made, the regeneration time would increase. As an example, if a hole was initially placed in the model and later removed, each time the model was regenerated the software would insert the hole and then remove it. Users got around this problem by placing portions of the model on separate layers and only regenerating the layers they were currently working with.

Part designs were stored in separate files. Designers could then combine these parts, some custom and some standard, in an assembly. Rather than creating copies of the individual parts in the assembly model, Pro/ENGINEER referred back to these individual part files. If a part was subsequently changed, the new version could propagate throughout the assemblies that used it.

The fact that constraints and dimensions could propagate between parts in an assembly was particularly impressive at the time. If one part had a projection that fit into a slot on another part and the size and shape of the projection changed, the slot would also change when the assembly was regenerated. Although not obvious at the start, another powerful aspect of PTC's software was that all applications worked off the same database. Within the Pro/ENGINEER suite of software, there was no need to translate model data from one format to another when the user switched applications.

The common data structure enabled PTC to incorporate bi-directional associativity between software modules. A change to the solid model resulted in changes to relevant drawings, analysis models and machine tool paths while a change to a drawing could change the model from which that drawing was derived. Users could decide whether this associativity was to be activated or not.

The weakest aspect of Pro/ENGINEER when it was launched probably was its inability to create engineering drawings without first building a model of the part or assembly. Many projects required simple two-dimensional drawings. Users ended up acquiring simpler packages such as

 

AutoCAD for these tasks or to add details to Pro/ENGINEER drawings that PTC's software was incapable of handling.

Early versions of Pro/ENGINEER were particularly amenable to the design of families of parts where the general shape of the part did not change, just one or more key dimensions.

**Changing the design paradigm**

The first two copies of Pro/ENGINEER were sold to Deere & Company for $14,000 in September 1987 by Dick Harrison. Delivery of production software began in January 1988. Within a year, PTC shipped nearly 900 copies of the software to about 150 customers and both potential customers and the media began to pay attention to this industry upstart. According to *The Anderson Report*, the aisle in front of the company's booth at AUTOFACT '88 was jammed and the company was profitable starting with the quarter in which it began shipping software. The expectation was that the company would have revenues of $10 in the fiscal year ending September 1989.[5] (It actually did slightly better with revenues of $11 million during its first full year of shipments.)

Fairly quickly, PTC began adding applications to the Pro/Engineer suite of software starting with a program for generating finite element meshes. By early 1989 these packages included:

**Pro/MESH –** This software supported the automatic generation of input data for finite element analysis directly from the Pro/ENGINEER model. Loads and boundary conditions were applied directly to the model and when the model changed, these changes were applied to the Pro/MESH generated data. Unwanted details such as bolt hole threads were suppressed at the user's option. This software was developed jointly with PDA Engineering. Price was $4,000.

**Pro/DETAIL –** PTC recognized fairly quickly that it had to support a reasonable level of production drafting. Drawing images were directly derived from the Pro/ENGINEER model such that changes to the model were immediately reflected in the drawings. Probably unique at the time was the bi-directional relationship between model and drawings. Not only were model changes reflected in the drawings but changes to the drawings also changed the model. Price was $3,000.

**Pro/INPUT –** This module enabled a user to input IGES 3.0 geometry and use that geometry as a non-parametric feature in a part model or as a component in an assembly. Price was $2,000.

**Pro/ASSEMBLY –** Although the basic Pro/ENGINEER software supported assembly modeling, Pro/ASSEMBLY provided additional features for working with large assemblies including hierarchical linked layouts, global dimensions and reference planes. Price was $2,500.

**Pro/DEVELOP –** This was a software development toolkit that enabled programmers to access the Pro/ENGINEER database. Price was $30,000.

The company's sales strategy involved a combination of Value Added Resellers, OEM resellers and direct sales. As of early 1989, 40 percent of sales was coming from international distributors while the domestic balance was 25 percent OEM, 20 percent

[5] *Anderson Report*, March 1989, Pg. 3

VARs and 15 percent direct. Early OEM partners were Control Data Corporation and PDA Engineering.

*The Anderson Report* interviewed several companies for its March 1989 article on PTC. The feedback was very positive. Jack Wiley of Deere & Company was quoted as saying:

> "Pro/ENGINEER is the best example I have seen to date of how solid modelers ought to work. The strength of the product is its mechanical features coupled with dimensional adjustability. The benefit of this combination is a much friendlier user interface plus an intelligent geometric database."

Similar positive feedback was reported by users at Harris Corporation and Noma Outdoor Products. The newsletter summed up its evaluation with:

> "The Pro/ENGINEER product is a real winner…..The Pro/ENGINEER product has been on the market long enough to expose any major technical flaws and there does not seem to be any." [6]

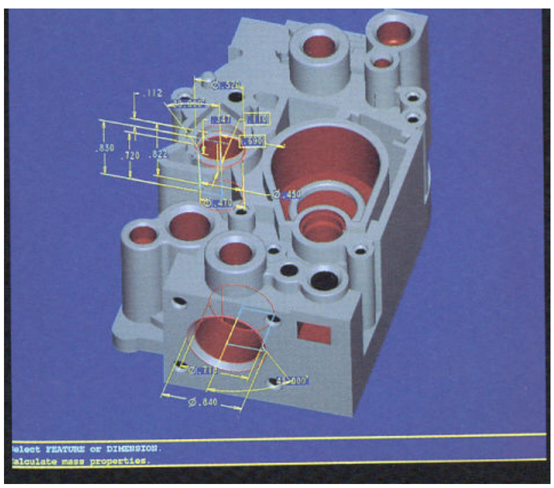

Figure 16.2
Typical Pro/ENGINEER Model

**Problems with the OEM Sales Model**

In mid-1989, Auto-trol Technology also became an OEM reseller. The difference between the OEMs and VARs was that the OEMs were responsible for both pre-sale and post-sale technical support and software delivery. Customers actually purchased software licenses from the OEMs while PTC processed orders initiated by the VARs. For undertaking these responsibilities, OEMs received a substantial discount while the VARs were paid a commission on what they sold.

From PTC's point of view, these OEM relationships were a way of jump-starting Pro/ENGINEER sales. The OEMs saw it as a way of expanding their traditional sales.

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[6] *The Anderson Report*, March 1989, Pg. 3

Auto-trol was a good example.[7] The company was having difficulty incorporating advanced solids modeling into its mechanical design software, Series 7000. Gary Germanis, a marketing manager in the mechanical software group, suggested that the company resell Pro/ENGINEER as a front end to Series 7000 which had strong drafting and NC capabilities. Initially, this was a sales strategy Auto-trol used without much success. In 1990, the company's focus shifted to selling Pro/ENGINEER on its own merits in specific geographic areas such as the West Coast.

The latter approach was starting to work when Auto-trol found itself competing with PTC's direct sales force. The issue was what defined a major account that would be the responsibility of PTC's own sales personnel. This was not resolved up front and Auto-trol found itself doing much of the account spade work only to have PTC subsequently declare that the prospect was a house account. The two companies were on a collision course over this issue when PTC simply decided in 1991 to terminate all its OEM reseller contracts and to offer those companies the ability to become more traditional VARs. Auto-trol declined this offer.

PDA Engineering's relationship with PTC was longer lasting than Auto-trol's. After a rocky start during which PDA threatened to sue PTC over a series of contractual issues, the two companies expanded their agreement in May 1990 to include a jointly developed software package, P/CONCEPT, that combined PDA's finite element technology with PTC's Pro/ENGINEER. Eighteen months later there was an announcement that the two companies had signed an expanded strategic agreement under which PDA's PATRAN 3 software would be able to directly access Pro/ENGINEER data.

**Pro/ENGINEER – Is it for real?**

In February 1990, Steve Wolf, the publisher of *Computer Aided Design Report*, decided that it was time to see if Pro/ENGINEER was for real. He had been taken aback by statement made by Geisberg and other PTC executives at AUTOFACT '89 that attempted to position PTC as a vendor comparable to industry leaders such as Prime Computer (Computervision), Intergraph and SDRC. He further thought that Geisberg's statement that PTC would become a billion dollar software company farfetched (it took nearly a decade but PTC did hit the billion dollar mark in 1998).

Wolf interviewed a number of Pro/ENGINEER users and came to the conclusion that while the software had a number of attractive capabilities it was far less mature than what the company claimed. His biggest concern was the difficulty designers had using this software to create complex surfaces. Wolfe felt that other vendors were farther ahead in doing this. Pro/ENGINEER's ability to handle complex parts and large assemblies was also questioned given the current state of UNIX workstation performance. Regeneration times as slow as 45 minutes for parts with 100 features were noted. Wolfe was also concerned by the fact that there were limits on the ranges of parameters as illustrated in Figure 16.3 below.[8]

[7] For about a year from late 1989 to late 1990, I was responsible for much of Auto-trol's Pro/ENGINEER sales activity in the United States.
[8] *Computer Aided Design Report*, February 1990, Pg. 1

 

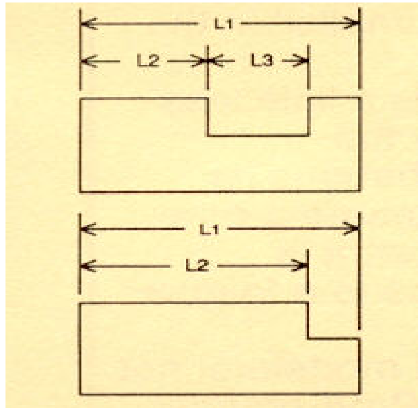


Figure 16.3
Pro/Engineer placed limits on the range of parameters.
(A designer could not increase the dimension of L2 to point that L3 vanished.)[9]

Wolfe went on to describe problems that an orthodontic manufacture had trying to do a Pro/ENGINEER benchmark. To avoid problems such as what this prospect encountered, PTC's application engineers were trained to use standardized demonstrations whenever possible. One they used extensively in the 1990 time frame was a household blender. The application engineers were well trained on these standard demonstrations which were implemented such that they illustrated the most positive features of Pro/ENGINEER and avoided any of the problems.

**PTC Quickly Gains Market Momentum**

Walske quickly put together an aggressive management team with Dick Harrison heading up sales, Lou Volpe as vice-president of marketing, Mike Payne running development and Mark Gallagher handling finances. Revenue grew rapidly from $11 million in the fiscal year ending September 1989 (the first full year of Pro/ENGINEER shipments) to $25.4 million in fiscal 1990 and $44.7 million in fiscal 1991.

Along the way, the company went public in December 1989 at $12 per share, more for the visibility and financial credibility than for the money it raised since PTC was profitable every quarter once it began shipping Pro/ENGINEER. Within two months the stock price more than doubled. It is interesting to note that two of the company's early directors, Donald Grierson, at one time been responsible for GE's Calma operation, and Noel Pasternak, a local lawyer, were still on PTC's Board of Directors 18 years later and Pasternak was the company's non-executive chairman.

According to Volpe:

> "They (competitors) would present the CAD/CAM purchase decision as one so strategic that it should be made only with an old-line CAD/CAM vendor. At that time it was not so much a technology sell as one of credibility, as in 'Would you commit your CAD/CAM investment to a

[9] ibid

 

> company that may not be around long enough to capitalize on its technology?'"[10]

I personally experienced the reluctance of potential customers to commit to radically new technology while responsible for Auto-trol's Pro/ENGINEER sales activity on the West Coast in 1990.

In sprite of the intrinsic conservatism of engineers, sales of Pro/ENGINEER did take off like a rocket. By mid-1991, the company had shipped 3,800 seats of its software, had established an impressive list of third party software partners and was turning out a new release of Pro/ENGINEER every six months like clockwork. In one break with industry tradition, PTC started to tout the number of enhancements (they were never considered bug fixes) in each release. For example, Release 7.0 issued in March 1991 was promoted as having 250 enhancements.

The pace with which PTC added applications to the Pro/ENGINEER suite also started picking up momentum. Among the packages introduced in 1990 and 1991 were:

**Pro/DRAFT –** Used to create two-dimensional drawings and add text and non-associative geometry to Pro/DETAIL drawings.

**Pro/FEATURE –** This package enabled users to create their own features and save them in a library for later use.

**Pro/SURFACE –** Early versions of Pro/ENGINEER were somewhat weak in terms of surface geometry definitions. Pro/SURFACE enabled users to add complex surface geometry to their models.

**Pro/SHEETMETAL –** This software enabled users to create sheet metal parts and prepare output for manufacturing the parts.

**Pro/MANUFACTURING –** Early releases of Pro/ENGINEER envisioned the use of third party packages for generating NC tool paths. Customers pushed PTC into developing its own NC software which worked directly with Pro/ENGINEER data. A change to the model could quickly be reflected in manufacturing data. It would take a number of releases, however, before this software measured up to industry demands.

**Pro/LIBRARY –** This was a library of over 20,000 parts and features that could be incorporated in Pro/ENGINEER parts and assemblies.

**Pro/PROJECT –** Pro/PROJECT was PTC's first attempt to offer project data management software. It was soon superceded by Pro/PDM.

In general, PTC tended to release new applications as quickly on the assumption that it was better to get them in the hands of users as soon as possible in order to garner feedback on what needed to be improved rather than wait until marketing said the package did everything they perceived customers wanted. The result was that some key applications such as NC manufacturing were released before they were ready and caused an unacceptable level of grief with customers. In other cases, this strategy worked well.

Although the base price for Pro/ENGINEER stayed at $9,500, the typical seat price was between $14,000 and $20,000 once users added the applications they needed for a complete solution. The computer and electronics industry was the main source of revenue for PTC with 60 percent of sales coming from this area. Aerospace made up 10 to 15 percent and automotive 5 to 10 percent.

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[10] Teresko, John, *Industry Week*, December 20, 1993

 

In addition to its partnership with PDA Engineering described above, PTC also was working closely with Swanson Analysis (ANSYS), Structural Research & Analysis Corporation and Rasna. All three firms were finite element analysis software companies with Rasna being somewhat different in that it focused on design optimization. As described below, PTC would eventually acquire Rasna while Dassault Systemes would eventually acquire SRAC.

According the June 1991 issue of *The Anderson Report*:

> "Parametric Technology came out white hot in 1988 and has cooled very little since….Its parametric geometry is just as appealing to users today as it was three years ago. It could be said that parametric modeling has become an industry standard since it is a check-off item on many users' CAD system spec sheets. And the scramble by other vendors to included some parametric capability demonstrates just how much PTC has raised user expectations for tools to make their jobs easier."[11]

Even Steve Wolfe became a believer by the end of 1991. In the December issue of the *Computer Aided Design Report* Wolfe wrote:

> "Parametric Technology Corporation's Pro/Engineer (sic) has become the hottest product for three-dimensional mechanical design………..The breathtaking growth of Parametric Technology should not surprise anybody."

Wolfe went on to list the reasons behind this attitude.

- PTC produced two releases of Pro/ENGINEER per year while competitors were lucky to get out one.
- Pro/ENGINEER was machine independent and PTC did not seem to have a favored platform vendor.
- New releases were available on all platforms at roughly the same time.
- The software was visually attractive and the software's menus used meaningful engineering terminology.
- Pro/ENGINEER only worked with solid models while competitive systems dragged along obsolete wire-frame and surface functionality.
- PTC's sales force worked hard and sold hard.[12]

**In the right place at the right time**

The early to mid-1990s were a time of very rapid growth for PTC. Many large user organizations had invested millions in first and second generation CAD systems and were beginning to realize the limitations of what they had installed. This led many users to re-evaluate the relationships they had with their current vendors and to look around to see if something better was available. PTC was the new kid on the block with a new bat and ball and soon everyone wanted to be its friend.

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[11] *The Anderson Report*, June 1991, Pg. 5
[12] *Computer Aided Design Report*, December 1991, Pg.2

 

In mid-1992 alone, the company secured an 800 seat order from Sandia National Laboratory and a 2,000 seat order from Caterpillar. The latter was a heavily contested battle with EDS' Unigraphics Solutions subsidiary. These were followed by other large orders from Cummins Engines and Ford Motor Company. The company's revenues and earnings were nearly doubling year over year and PTC's stock had tripled between early 1991 and mid-1992 when the installed seat count had climbed to 8,300.

The October 1992 issue of *Engineering Automation Report* tried to put PTC's growth in perspective. It identified a number of reasons why the company was successful while its competitors were struggling. As I wrote at the time:

> "When opportunity came knocking, Parametric Technology was there to answer the door. To appreciate why PTC has been so successful, you need to look at the history of the CAD industry and where the technology stood when the company was formed in 1985."[13]

The article went on to explain that competitive systems such as CADDS, BRAVO, Unigraphics, DDM, CADAM and CATIA had roots that went back to the late 1960s in some cases. These packages mostly evolved from two-dimensional drafting-centric applications with three-dimensional and solids data added at a later time. They were mainframe or minicomputer based with considerable software implemented to compensate for the shortcomings of early hardware products and operating systems. The software relied on proprietary operating systems and carried forward code needed to support legacy hardware which was not longer of interest to new buyers. For the most part, these systems were hard to maintain and enhance and were particularly difficult to port from one computer platform to another. In some cases, portions of the code was still written in assembly language.

PTC sought to achieve a competitive advantage by creating new technology tuned to the characteristics of networked UNIX workstations. Pro/ENGINEER was implemented from the start with a double precision database, written in the highly portable C programming language and took advantage of the latest capabilities provided by most UNIX operating systems. The one exception was support of DEC's rather mature VMS operating system. But even here, PTC supported DEC's single-user workstations, not its multi-user minicomputers.

As described earlier, the result was a software product line that was built around a single database, parametrically defined geometry, feature-based solids modeling, and bi-directional associativity between applications. In the latter case, the extent to which a downstream application could change the geometry of the original model was controllable by the user or system administrator. The resultant system had a user interface that incorporated many of the latest on-screen menu techniques and color coded feedback mechanisms. It was designed specifically to function in a distributed network of workstations and was implemented on all supported platforms in parallel.[14]

By the late 1992, Pro/ENGINEER was at Release 10 with another 700 enhancements and over 25 application packages supported. Some of the more recent additions included Pro/MOLDESIGN, Pro/CABLING, Pro/DIAGRAM and

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[13] *Engineering Automation Report*, October 1992, Pg. 6
[14] *Engineering Automation Report*, October 1992, Pg. 6

 

Pro/HARNESS-MFG. More and more, PTC was offering a nearly complete design, drafting and manufacturing solution - relying less and less on third-party applications except for analysis and some specialty areas such as high-end visualization, rapid prototyping and documentation. The software was primarily sold in suites such as the Production Package which consisted of Pro/ENGINEER, Pro/ASSEMBLY, Pro/DETAIL, Pro/FEATURE, Pro/INTERFACE and Pro/PLOT, all for $18,000.

**Problems with parametric design**

The *Engineering Automation Report* article also began to explore the question about the extent with which users had to plan their design work in order to avoid having to start over if major changes were made to the design. The problem with a pure parametric design technique that is based upon regenerating the model from its history tree is that as geometry is added it is dependent upon geometry created earlier. This methodology has been described as a parent/child relationship except that it can be many levels deep. If a parent level element is deleted or changed in certain ways it can have unexpected effects on child-level elements. In extreme cases (and sometimes in cases that were not particularly that extreme), the user was forced to totally recreate the model.

The way around this problem was to carefully plan the design, defining ahead of time which major elements would be dependent upon other elements. Some people described designing with Pro/ENGINEER to be more similar to programming than to conventional engineering design. Competitors, particularly SDRC, which used an alternative technology called "variational design" that did not require the model to be fully constrained at all times, claimed that their software avoided this type of situation.

The other problem with Pro/ENGINEER that was beginning to concern users was the reduced performance when working with large assemblies or very large individual parts. These models could take a considerable amount of time to load (retrieve from disk memory and prepare for interactive manipulation) and to regenerate when changes were made. Faster computer systems helped but users were starting to build increasingly complex models. Model size was increasing faster than the speed of the newest computers could handle.

In succeeding years, PTC would invest considerable development resources addressing both of these problems.

**PTC matures as a company**

PTC ended 1992 with a quarter that saw revenue grow 97 percent to $32.5 million. I was fairly enthusiastic about the company's future and predicted that PTC would be a $500 by 1995. I was close in that the company reported revenues of $394 million for the fiscal year ending September 30, 1995 and $600 million the following fiscal year.[15]

I was not the only writer who was becoming enthralled with PTC. In the November 1992 issue of *Computer Aided Design Report* Steve Wolfe stated:

> "The secret of PTC's success is not hard to understand. It delivers a three-dimensional CAD/CAM system that is significantly easier to use than the established systems. Its dimension-driven modeling capabilities,

[15] *Engineering Automation Report*, February 1993, Pg. 15

 

> employment of features instead of drafting elements, and fast interactive response all contribute to the product's ease of use."[16]

One negative was that PTC was gaining the reputation as being a overly aggressive company in regards to its sales force, particularly as an increasing portion of sales were being handled by the company's own personnel. It was not at all uncommon for a PTC salesperson to pick up the telephone and call the president of a company if he or she felt that the people responsible for selected a CAD vendor were leaning towards a competitor. Many of these calls were not particularly flattering in regards to these lower level individuals. The result was a significant number of engineering managers who would have nothing to do with PTC even if the company's systems might have been a good solution for their needs. A decade latter, PTC was still trying to convince the marketplace that it was a "kinder and gentler" vendor.

PTC also had a reputation among resellers as being very hard to work with. As a consequence, there was a lot of turnover among the companies reselling Pro/ENGINEER. One exception was Rand Technologies, a Canadian-based reseller with numerous offices in the United States. Actually, it was the operating arm of a company named Rand A Technology Corporation. Rand, which had been established in 1986 as a reseller of Computervision software, was headed by Brian Semkiw. It sold a number of complementary software packages as well as hardware on which to run these programs.

As of early 1994, when the company went public in Canada, 38 percent of its total revenue consisted of Pro/ENGINEER software and related PTC applications. It claimed to have sold seven percent of all Pro/ENGINEER seats installed worldwide. The company stated that its success was a result of the high level of support it provided customers. But even this close relationship with PTC would eventually blow up and the two companies would part ways with much animosity.

**Explosive growth continues**

From a reported $163 million in fiscal 1993, PTC's revenues exploded to $809 million in fiscal 1997. Along the way, the company's earnings increased from $43.5 million to $219 million and the cumulative number of seats of Pro/ENGINEER sold exceeded 100,000. It seemed as if the company could do no wrong. One point that needs to be emphasized is that this revenue involved pure software along with some consulting services. The company's major competitors had traditionally sold hardware either manufactured themselves or OEMed from computer and other hardware manufacturers.

As the market price of computer hardware plummeted, these companies had a hard time increasing revenues or even maintaining them at historical levels. When PTC ported its software to PCs running Windows NT, it did not matter to the company that the hardware cost for a seat of Pro/ENGINEER had dropped significantly since it received the same revenue for Pro/ENGINEER whether it ran on a $40,000 UNIX workstation or a $4,000 PC. In fact, if anything, the trend to lower priced hardware enhanced PTC's position in that customers could use a larger portion of their budget for software since they were spending less for hardware.

Mentioning Windows NT, when Microsoft announced its new operating system on May 24, 1993, PTC was one of the first software companies to jump on the

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[16] *Computer Aided Design Report*, November 1992, Pg.1

bandwagon. The company said that it would have Pro/ENGINEER running on Windows NT when the operating system began shipping in July. The company didn't quite make that date but it did begin shipping a Windows NT version of Pro/ENGINEER certified on the Compaq DESKPRO 5/60M in August. Because of slight differences between PCs, PTC planned to test the software on each preferred configuration before giving that combination of hardware and software its blessing.

By late 1993, large million dollar plus orders were coming fast and furious. In particular, companies that had installed a few seats of Pro/ENGINEER to evaluate the technology liked what they saw and decided to roll out the software to their entire design staff. A good example was Paccar, the builder of Kenworth and Peterbuilt heavy trucks. They started with seven seats at Kenworth, liked what they saw and subsequently ordered another 63 seats.

According to the November 1993 issue of *Engineering Automation Report*:

> "The speed with which existing PTC customers are upgrading their installations is impressive. We see two messages here. On one hand, these companies are finding Pro/ENGINEER to be an effective tool and they are willing to commit increasingly large sums to purchase additional copies of software and hardware on which to run it. But the second issue is that there appears to be a huge pent-up need for new engineering design technology that was not being met by the previous software vendors these companies were using. The vendors of these legacy systems have provided a window of opportunity to PTC and PTC is taking advantage of it."[17]

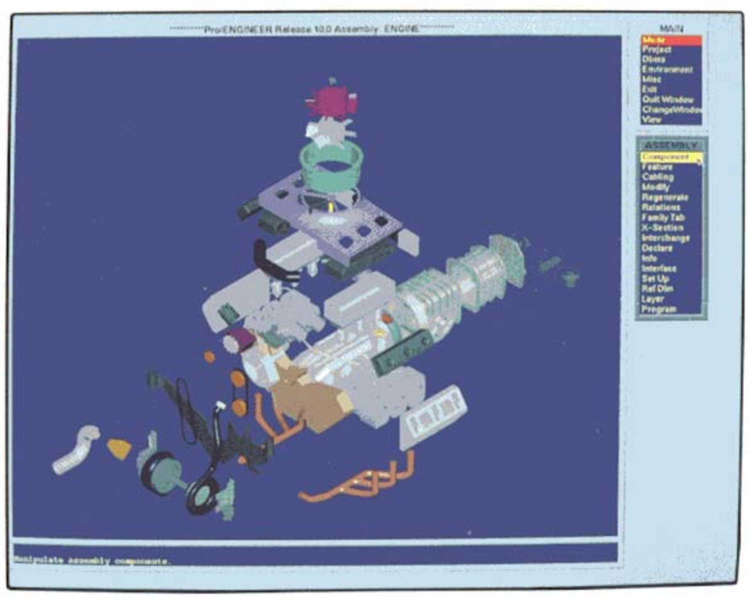


Figure 16.4
Pro/ASSEMBLY circa Pro/ENGINEER Release 10

[17] *Engineering Automation Report*, November 1993, Pg. 5

**Cleaning up its manufacturing software**

In late 1993, PTC began shipping Pro/ENGINEER Release 12 with a number of sketching and design enhancements and support for a total of 27 individual applications. The most significant enhancement, however, was a substantial overhaul of Pro/MANUFACTURE. While the initial versions of this software had some strong capabilities, especially the bi-directional associativity with the Pro/ENGINEER database, it was awkward to use and did not provide sufficient ability for users to directly create and edit tool paths. This had resulted in a near revolt among a number of PTC customers, led particularly by Caterpillar.

The Release 12 version of Pro/MANUFACTURING improved the software's user interface by tailoring the number of menu options presented to the user. For example, if the user was doing three-axis milling, only commands applicable to that type of machining would appear on the screen. Fundamentally, the software was rewritten to more closely reflect the way manufacturing engineers worked.

The other significant change was that the user was now provided more control over machining operations rather than depending on the automatic generation of tool paths. In fact, the manufacturing engineer could totally bypass the automatic generation of tool paths and create them interactively. This interactive set of tool paths was remembered by the system as a feature and if the model shape changed, then the interactive tool paths could be automatically updated.

PTC also added a Pro/PIPING module that enabled designers to add pipe and tubing components to an assembly model. The software included a library of components that had design specifications associated with them. If a user inserted a piece of copper tubing in an assembly, the software would check to ensure that it did not exceed bend limitations contained in the specifications for that size tubing.

Release 13 came out in early 1994 with more enhancements to Pro/Manufacturing including the ability to machine across multiple surfaces. This software also incorporated additional decision making logic such as the ability to make a sequence of machining operations dependent upon the thickness of a plate. The result would be if the plate were thin then holes would be punched but if the plate was thicker than a specified amount or if the correct size punch were not available, then the holes would be flame cut.

Several new applications were made available with Release 13 including Pro/FEM-POST. This software enabled a user to create a finite element mesh with Pro/FEM, send the data to a FEA program, receive back the results and view them with Pro/FEM-POST and then make changes to the model geometry based upon these results. In effect, the user could stay in Pro/ENGINEER through the entire process except for the actual analysis step.

Another new application was Pro/SCAN-TOOLS which allowed users to take data from three-dimensional scanning devices and convert that data to Pro/ENGINEER-compatible surface geometry. Since a lot of industrial design was still being done by creating clay or wood models, this software closed an important gap in automating the design process. Pro/SCAN-TOOLS could also be used to reverse engineer existing parts.[18]

Just about every month during the 1994 and 1995 time frame, PTC announced million dollar plus contract awards from Sharp Corporation, Whirlpool, Ford Motor,

[18] *Engineering Automation Report*, April 1994, Pg. 12

Groupe Schneider, Mannesmann AG, Steelcase, Sharp, Eaton, Cincinnati Milacron, AMP Incorporated and others.

**PTC's management changes**

PTC started a new phase of its evolution as a significant technology firm in August 1994 when Steve Walske replaced Sam Geisberg as chairman of the company's board of directors and Dick Harrison was promoted to the position of president and chief operating officer. Geisberg stayed with the company for a short while as chief scientist and then retired. Lou Volpe, who many people thought might get the COO position, left the company later that year.

Meanwhile, the company kept chugging out new Pro/ENGINEER software releases every six months. This continued to impress most industry observers. The following comment in the December 1994 issue of *Computer Aided Design Report* was typical of what was being written at the time.

> "Parametric Technology may lose its edge and go the way of the turnkey CAD vendors if it doesn't keep up with technological trends. At this point, however, it shows no signs of doing so. It is constantly improving its core software and related applications. It seems better positioned than other high-priced competitors to take advantage of the shift from Unix work stations to Windows NT and personal computer hardware. It is expanding aggressively outside the U.S. and it has a respectable, if not large, dealer channel selling $40 million worth of new software each year. None of the old-time CAD vendors is doing all these things, let alone doing them well. Parametric Technology is becoming the market leader because it has better software, adds requested improvements more rapidly than its competitors, sells aggressively, keeps in step with hardware trends, and provides good application engineers to help train its customers. It continues to baffle us that the other large CAD vendors don't respond in kind."[19]

**Creating a lower cost alternative**

A significant product announcement occurred in January 1995 when PTC launched Pro/JR. The intent was to provide a lower cost solution to the estimated 600,000 potential users who needed greater capability than that provided by low-cost mechanical drafting packages but something less than what was provided by the full Pro/ENGINEER suite of software. Pro/JR. was a subset of Pro/ENGINEER Release 14 and was available in both UNIX and Windows NT versions. The price was initially set at $8,000 for a node-locked license and $9,000 for a floating licenses that could be moved from computer to computer in a network as needed.

This price seemed to be somewhat high compared to Pro/ENGINEER's base price of $9,500 except that one needed a fair number of optional modules to make Pro/ENGINEER a useable solution. PTC packaged these in suites called the Basic Package and the Advanced Designer package for $16,000 and $20,000 respectively. Pro/JR. included a subset of Pro/ENGINEER and Pro/DETAIL along with a number of

[19] *Computer Aided Design Report*, December 1994, Pg.9

the capabilities provided in Pro/FEATURE and Pro/INTERFACE as well as a version of Pro/PLOT. Overall, Pro/JR. was a decent collection of functions at what was then a reasonable price. PTC described it as 50 percent of the Basic Package at 50 percent of the price. (Other sources said 40 percent of the functionality for 40 percent of the price.)

Pro/JR. utilized a streamlined version of Pro/ENGINEER's menu structure. Functions that were not applicable were removed making the menus simpler to use. A developer's toolkit was available for $6,000 that enabled third party software firms to adapt their Pro/ENGINEER applications to Pro/JR.

Initially, it appeared that PTC had come up with an attractive product that filled a significant gap in the industry's product offerings. There were a vast number of organizations that either could not afford a full-functioned Pro/ENGINEER license for every design engineer or were not ready for the extensive changes in design procedures that software necessitated. Pro/JR. clearly offered a more integrated solution than Autodesk's AutoCAD Designer product which sold for $6,750 and greater mechanical design capability than Bentley's MicroStation Modeler. The company was clearly aware of the pending introduction later that year of SolidWorks and Intergraph's Solid Edge, the two packages that would help establish a new market for mid-range solutions.

So why did Pro/JR. fail to catch fire and excite the market?

- It was probably priced somewhat too high. The sweet spot for this type of application was probably closer to $5,000 than $8,000. Also, $1,400 annually for full maintenance and support per copy was considered quite high.
- The choice of the name for the product was probably a mistake. Engineers did not want to be assigned to use a "junior" product.
- The use of Pro/JR. by existing Pro/ENGINEER customers was limited by the fact that while data created with Pro/JR. could be imported and used by Pro/ENGINEER, Pro/JR. could not import and use Pro/ENGINEER data. This was more a marketing decision by PTC than a technical limitation.
- No optional Pro/JR. applications were available from PTC. If a customer wanted to machine a part created in Pro/JR., either a new third-party package developed for use with Pro/Jr. had to be purchased or the data had to be exported to Pro/ENGINEER.
- The fact that Pro/JR. was sold only through the company's reseller channel resulted in sales conflicts between the VARs and PTC's direct sales force.
- There was no company provided training. The only options were training programs offered by the VARs or self training.[20]

**PTC expands through acquisitions**

In the February 1995 issue of *Engineering Automation Report*, I noted that PTC had accumulated over $230 million in cash reserves and that I would not be surprised to see them use this money to acquired either a product data management or electronic design software vendor.[21] The company moved sooner than I expected and in directions other than what I had expected.

[20] *Engineering Automation Report*, February 1995, Pg. 10
[21] *Engineering Automation Report*, February 1995, Pg. 14

The first move the company made was to announce on April 12, 1995 its plan to acquire Evans & Sutherland's industrial design and visualization software business unit for $33.5 million in cash. The deal included E&S' Conceptual Design and Rendering System (CDRS) and 3D Paint products and the staff that had been working on them. This group had software revenues of about $8 million annually. The key product was clearly CDRS which was a functionally rich industrial design and styling software package. Many PTC customers already used software products from Alias and Wavefront, both of which had recently been acquired by Silicon Graphics.

E&S was formed in 1968 by Dr. David Evans and Dr. Ivan Sutherland, both of whom were computer science professors at the University of Utah at the time. The initial plan was to develop graphics hardware that could be used for computer-based simulation applications. This led the company into the business of developing and producing graphics hardware for aircraft flight simulation systems. E&S subsequently established a partnership with a British simulation firm, Rediffusion, which resulted in the company having exclusive rights to provide visualization systems for Rediffusion's commercial flight simulators. Many of today's commercial aircraft pilots were trained on these systems. E&S went public in 1978.

Sutherland stayed with the company for just a few years while Evans remained CEO until 1994. During the 1980s, the company expanded into new graphics markets including general visualization, industrial styling and solids modeling having acquired Shape Data and that company's Romulus package in 1981. CDRS was introduced in 1990 and although it was a visually impressive package, it never sold well, partially due to the lack of an adequate sales and marketing organization but perhaps more importantly, its high price. Initially, CDRS was only available on E&S workstations and a complete single user system sold for $250,000. Subsequently, CDRS was ported to other UNIX workstations but was still priced at $55,000 to $85,000 for just the software, The 3D Paint visualization software was only available on SGI's high-end Onyx workstations and was priced at $15,000.

James Oyler joined E&S in 1994 as president and CEO and he soon began to refocus the company on its core competencies: simulation training, high-end visualization and digital theaters. Corporate sales were slipping since Rediffusion was no longer a customer and E&S had incurred its largest loss in a decade in 1994. CDRS and 3D Paint did not fit into Oyler's plans for the company.

CDRS, along with the 3D Paint software, was expected to provide PTC with an integrated industrial design and product engineering solution suite. While the surface geometry capabilities in Pro/Surface were adequate for many design tasks, CDRS had far superior overall surface creation and editing functionality, particularly as used in the design of automobile bodies. Integrating the CDRS technology into the Pro/ENGINEER product would end up taking much longer than initially expected.

There was also an ulterior motive for PTC in this acquisition. Ford Motor Company was a major user of CDRS and Ford was currently engaged in the process of selecting a primary CAD vendor. PTC was in the running for this business and one has to assume that the company thought the addition of CDRS to its product offering would provide a competitive advantage. This gambit did not work and Ford ended up selecting SDRC as its primary CAD vendor.

Dr. Thomas Jensen, who received his Ph.D. from the University of Utah in 1984, had earlier joined E&S in 1978. He became general manager of the company's design software group in 1993. As soon as the acquisition was completed, Jensen moved from Salt Lake City to Waltham and became vice president of R&D at PTC. Jensen never seemed to fit in with the Massachusetts-based developers at PTC and left the company in 1998. He subsequently became vice president of R&D at think3, a position he held until around 2003. [22,23]

Within a few months, PTC repackaged CDRS and 3D Paint as Pro/ENGINEER options. CDRS became Pro/DESIGNER, priced at $12,000 per copy or less than half what E&S had been charging. Data was transferred between Pro/ENGINEER and Pro/DESIGNER using a neutral format based on IGES. For customers using CDRS in a stand-alone mode or with other CAD solutions, PTC offered Pro/CDRS, priced at $25,000 per copy. Other E&S software was repackaged as Pro/PHOTORENDER, Pro/ANIMATE and Pro/PERSPECTA-SKETCH. A bundle of Pro/ENGINEER, and the former E&S software was offered at the extremely attractive price of $20,000 per copy. One problem in this area was that the E&S software only ran on IBM and SGI workstations and it would be sometime before these capabilities would be available on other UNIX workstations and running under Windows NT.

A few months after the CDRS acquisition, PTC made a significantly more impressive move when it acquired Rasna Corporation, a vendor of design analysis and optimization software, for approximately 3.8 million shares of stock worth about $205 million at the time. Rasna was founded in November 1987 by George Henry and several associates who had worked on similar technology at IBM's Almaden Research Center in San Jose, California. The company's MECHANICA software differed from traditional finite element method packages in that it used a technique called Geometric Element Analysis (GEA). A GEA model uses significantly fewer elements and these elements can contain fairly complex geometry. Within the mechanical analysis community, these were known as p-elements where the p stood for polynomial.

A key aspect of Rasna's MECHANICA software was that it not only handled structural, thermal and motion analysis of parts and assemblies but that it could also be used to optimize the shape of individual parts. Initially, Rasna worked closely with Autodesk to provide this technology to AutoCAD users but the company soon switched focus to Pro/ENGINEER. The MECHANICA process as of 1995 worked as followed:

1. Basic part geometry was defined in a CAD system such as Pro/ENGINEER, CADKEY, AutoCAD or I-DEAS.
2. The geometry was imported into Applied Structure, one of the MECHANICA modules.
3. The user created a p-element model using automated and interactive techniques. Typically, a Rasna model had about one fiftieth the number of elements that a traditional FEA model for the same part would have.
4. Loads and boundary conditions were applied.
5. The user defined which parts could be changed such as the width and/or thickness of a particular portion of the model and what was to be optimized such

[22] *Engineering Automation Report*, April 1995, Pg. 5
[23] *Computer Aided Design Report*, April 1995, Pg. 5

as weight or stress. Minimum and maximum values were also defined at this point.

6. The software would then iterate through the analysis until it found an optimum shape for the part. In the mid-1990s, these runs typically took from several minutes to several hours on a UNIX workstation. Traditional FEA models could take several times as long on much larger and more expensive computers to simply do the analysis.

7. The modified geometry was exported to the originating CAD system and the model was interactively changed to conform to the optimized shape.[24]

In addition to Applied Structure, which handled basic linear analysis, Rasna also offered thermal, motion, nonlinear, and buckling modules. The software at the time of the acquisition ran on UNIX workstations, Windows NT and several supercomputers. Software was available to transfer geometry between MECHANICA and a number of CAD packages although Pro/ENGINEER seems to have been the preferred CAD system. This was expensive software with prices starting at $16,000 for a one station license. It could pay for itself on one design assignment, however, by reducing the weight of a part – especially if that part was to made in the millions.

In the January 1995 issue of *Engineering Automation Report* I provided an update on Rasna and suggested that the company, which was expected to do around $35 million that year, would go public before the year was over. When Rasna opted to be acquired rather than go public, I asked David Pidwell[25] why the acquisition rather than a public offering. He responded: "The synergistic benefits are tremendous, both in the sales and the product areas….If we didn't join them, we would end up fighting them." Pidwell went on to say that merging with a fast growing company (PTC was growing about 45 percent per year at the time) was similar to an IPO without the aggravation and expense an IPO would have entailed. He described it as "an instant IPO."[26]

Of Rasna's more than 1,200 customers at the time of the acquisition, perhaps half used a CAD system other than Pro/ENGINEER. The early word from PTC was that the company would continue to sell MECHANICA to these users. This never really happened to any extent for two reasons: 1)PTC saw MECHANICA as a competitive advantage when selling Pro/ENGINEER particularly against companies such as SDRC that had their own analysis software and 2)PTC fired most of the Rasna sales staff soon after the acquisition. The company did land a $1.9 million contract from McDonnell Douglas for MECHANICA software in September 1995 but there were few others of this ilk. PTC expected its own 300-person sales staff to sell about $60 million of analysis software in fiscal 1996. This proved to be widely optimistic but a more than decade later Pro/MECHANICA is still an important part of PTC's software product line.

**PTC shifts into an even higher gear**

By mid-1995, it appeared that PTC would soon become the dominating company in the CAD industry. It was growing rapidly while most of its competitors were

[24] *Engineering Automation Report*, April 1993, Pg. 6

[25] David Pidwell subsequently joined a venture capital firm, Alloy Ventures, while Keith Krach, Rasna's COO went on become founder and chairman of Ariba.

[26] *Engineering Automation Report*, July 1995, Pg. 1

 

struggling. Since PTC had never built or resold computer hardware, it did not suffer the withdrawal pains experienced by competitors such as Computervision, Applicon, Intergraph or Auto-trol Technology. Pro/ENGINEER created a paradigm shift in the world of mechanical design software, a change that competitors were just catching up to.

Not only was PTC's revenue continuing to grow at an impressive pace, but the company was also significantly profitable due to a number of factors.

- As the company's revenues increased, there was not a commensurate growth in the company's overhead staff. PTC was a very lean operation in the mid-1990s.
- The company prided itself in the size and aggressiveness of its sales staff. The plan was to have 375 sales people on board by the end of fiscal 1995 (they actually ended up with 400). These individuals were responsible for over 90 percent of the company's revenue while resellers handled the balance. Combined, the two sales forces sold 15,900 seats of Pro/ENGINEER during 1995 at an average price of $18,100. As mentioned earlier, the sales force's aggressiveness had negative connotations as well as positive. PTC management recognized this problem and already was starting to talk about toning down the rhetoric.
- PTC's sales staff effectively used a technique sometimes referred to as "guerilla sales." The concept was to sell a few seats of Pro/ENGINEER to a department within a large corporation and then use the success of those systems to eventually have the customer commit to making the software a corporate standard. Autodesk also used this technique very effectively.
- While feature-based parametric design was what initially caught the attention of potential users, the single integrated database for multiple applications eventually was seen as being equally important.
- Since Pro/ENGINEER was implemented from the start to be platform independent, PTC had to spend far less effort porting its software than did competitors.
- In general, PTC had good relationships with third-party software vendors, even after acquiring Rasna.
- The company encouraged users to submit requests for enhancements and set up user committees to help review these requests. The manufacturing software committee was particularly vocal in its opinion of what the company had to do to make that software more effective.
- Pro/ENGINEER customers were beginning to reduce or even eliminate drawings as part of the design process and were transferring design data directly to manufacturing suppliers such as tool and die shops in the form of Pro/ENGINEER models. This required the suppliers to also use Pro/ENGINEER.
- While other software companies tended to spend 20 percent of more of their gross revenues on product development and software maintenance, PTC was spending just 6.5 percent. At the end of fiscal 1995, PTC had only 340 people involved in product development as compared to nearly 1,100 people in the company's sales and marketing organization.

In general, PTC kept cranking out new releases of Pro/ENGINEER every six months, typically with 500 or so enhancements and several new applications. Release 15 was no different although it was delayed a few months in order to incorporate Pro/DESIGNER. While the basic interface had not changed much since the software's first release, PTC did work hard to make it more effective. As an example, Release 15 allowed a user to interrupt the design of a part, create a new customized feature and then insert that feature in the model. At the time, this was an impressive capability. The company was also starting to pay more attention to the performance problems associated with working on large assemblies.

Pro/JR. had gotten off to a slow start with sales of $5 to $7 million in fiscal 1995 but the company expected this to grow to $20 to $30 million in fiscal 1996. In October the company reduced the price of that package from $8,000 to $4,995. Obviously, PTC was starting to become concerned about new mid-range competitive solutions such as Intergraph's Solid Edge which was priced at $5,995, SolidWorks which was initially priced at just $3,995 and Autodesk's Mechanical Desktop priced at $6,250.

PTC was also beginning to pay more attention to product data management issues. Pro/PROJECT morphed into a newer packaged called Pro/PDM where PDM stood for Parametric Design Manager. Unlike Pro/PROJECT, Pro/PDM did not require an active Pro/ENGINEER license in order to be used. PTC saw Pro/PDM as project-level or department-level data management software and was comfortable at the time working with other software vendors such as Sherpa and Workgroup Technology that provided enterprise-level data management applications.

By mid-1995 PTC had installed over 40,000 seats of Pro/ENGINEER and Pro/JR. at more than 6,200 organizations around the world. It was adding 600 new customers and about 4,000 seats a quarter. In the August issue of *Engineering Automation Report* I wrote:

> "PTC has its sights set on becoming a $1 billion company by the end of the decade. If the market potential is as real as they believe it to be, there are no competitors currently strong enough to prevent the company from meeting this objective. It is unlikely that the growth will come purely from mechanical design. We believe that PTC will need to become a more significant factor in the rapidly growing PDM market."[27]

To put the potential growth in perspective, The company finished fiscal 1995 with revenues of $394 million, up 48 percent from the prior year.

In September 1995, Edwin Gillis joined PTC as chief financial officer. He had previously held the same position at Lotus. In addition to Walske and Harrison, other key executives were Marc Delude, senior vice president of marketing, Dr. Thomas Jensen, senior vice president of research and development and Michael McGuinness, senior vice president of sales and distribution. Among the company's directors were Donald Grierson who had previously headed up General Electric's "Factory of the Future" initiative (See Chapter 11) and Michael Porter, a professor at the Harvard Business School and a leading authority on corporate re-engineering.

### A changing sales and low-cost product environment

[27] *Engineering Automation Report*, August 1995, Pg. 6

 

In 1996, revenue was continuing to grow by over 50 percent. Quarterly sales volume was rapidly approaching 6,000 seats with quarterly revenue over $150 million. By mid 1996 PTC had over 600 sales people on board and was talking about increasing that number to 900 by the end of fiscal 1997. The target was to increase revenues to around $850 million during the next year. Walske believed that he could keep a sales force this large productive by a high ratio of managers to direct sales people. In PTC's case this was around one to one.

Having such a large sales force tended to reduce the size of individual sales territories which meant that PTC's people were calling on smaller and smaller accounts. This resulted in an increased level of competition with resellers and PTC decided to change its relationship with its VARs. Except for Canadian-based Rand Technologies[28], the VARs were no longer able to sell Pro/ENGINEER but were limited to selling Pro/Jr. which was renamed Pro/MODELER. It was a more complete product now, however, with several application packages including Pro/MILL, Pro/TURN, Pro/FEA and Pro/RENDER, each selling for $3,000 to $4,000.[29]

A few months later, the nomenclature changed again and this software product line was renamed PT/Products with Pro/MODELER becoming PT/Modeler, Pro/MIL becoming PT/Mill, etc. There was also a library of 34,500 ANSI fasteners called PT/Basic Library which sold for just $1,000. The version of PT/Modeler that was released in the fall of 1996 was based on Pro/ENGINEER Release 17 and was available in both Windows 95 and Windows NT versions. A UNIX version of this software was no longer available.[30] Its price dropped once again in early 1997, this time to just $2,995 and the prices of some optional modules were also lowered. Bundles were available at a discount from the list price of individual packages. A fairly comprehensive suite of design and manufacturing modules was available for just $6,995.

A major issue with PT/ Modeler was that it still used the same UNIX-oriented user interface as Pro/ENGINEER even though it was only available on Windows-based PCs. Users of moderately priced design software on PCs expected applications to have a user interface based on Windows standards. How much this adversely impacted sales of the PT/Products packages is not clear. Possibly more significant was that fact that this software was only sold by resellers who could not sell Pro/ENGINEER. This created conflict with PTC direct sales force and the PT/Products line probably never got the corporate support it needed to be successful.

In addition to reducing prices for the PT/Products packages, PTC once again change its distribution strategy. The company's direct sales force was given authorization to sell these low cost packages which strained PTC's relationship with its resellers even more than it had been. It also was not encouraging to hear the company's CEO putting down the concept of mid-range CAD software. At an analysts meeting on April 10, 1997 Walske commented:

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[28] By the end of 1996, Rand determined that its future was not in selling Pro/ENGINEER and the company announced that it would phase out this aspect of its business by April 1999 and focus on systems integration. In this regard, Rand became PTC's first Preferred Systems Integration Provider and PTC acquired a small equity interest in Rand.

[29] *Engineering Automation Report*, August 1996, Pg. 1

[30] *Engineering Automation Report*, October 1996, Pg. 3

 

"Our perspective on low-end products has not changed. They provide most but not all of the functions of Pro/Engineer. Our customers demand end-to-end design automation. I don't think SolidWorks will close the gap. SolidWorks [and all the other low-priced systems] are fundamentally flawed."

In response to another question at the meeting, Walske said:

"Our main competition is not with SolidWorks, but with Autodesk."[31]

**Focus on automotive market**

Towards the end of 1996, Don Henrich was promoted to the position of senior vice president of marketing replacing Marc Delude who left the company to become president of Moldflow, an analysis software company. Meanwhile, multi-million dollar contracts continued to pour in from companies around the world including Matsushita Communications, SKF Group, Sanyo and Lockheed Martin Astronautics. The company ended its fiscal 1996 with revenue of $600 million, up 52 percent from the prior year. This revenue represented 23,000 seats of software at an average price of $20,400.

The company planned to release an exciting new package along with Release 18. Called Pro/ENGINE, it was intended to automate about half the work that went into the design of an automobile or truck engine. Pro/ENGINE combined typical Pro/ENGINEER functionality along with new web technology. The package consisted of three major components as shown in Figure16.5:

- A Web browser-enabled tutorial on designing an engine
- A series of "wizards" that facilitated each step of the design
- Pro/ENGINEER to do the actual part and assembly modeling.

PTC had developed all the parametric relationships between the different parts so when a value such as the stroke of a piston was modified, that change would propagate throughout the entire engine model. The web aspects of this package were intended to also be made available separately to customers as Pro/ Web Modeler.

Typically, this level of design automation was something that large users did for themselves. It would prove interesting to see if a software vendor's more intimate knowledge of its software would offset a customers more intimate knowledge of its work processes.[32] PTC declared 1997 to be "the year of the car." The company's intent was to develop applications that could be used to penetrate the automotive design industry more extensively than PTC had been able to do to date. A Pro/BODY package was being developed to go along with Pro/ENGINE.

Potential customers were expecting PTC to integrate the surface technology acquired with CDRS more closely with Pro/ENGINEER than the current enhanced IGES interface used with Pro/DESIGNER. The Pro/ENGINEER technology model was built around the concept of data associativity between applications. The underlying CDRS architecture was substantially different from that of Pro/ENGINEER, making the integration of the E&S and PTC software more difficult that initially envisioned.

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[31] *Computer Aided Design Report*, May 1997, Pg. 1
[32] *Engineering Automation Report*, November 1996, Pg. 14

 

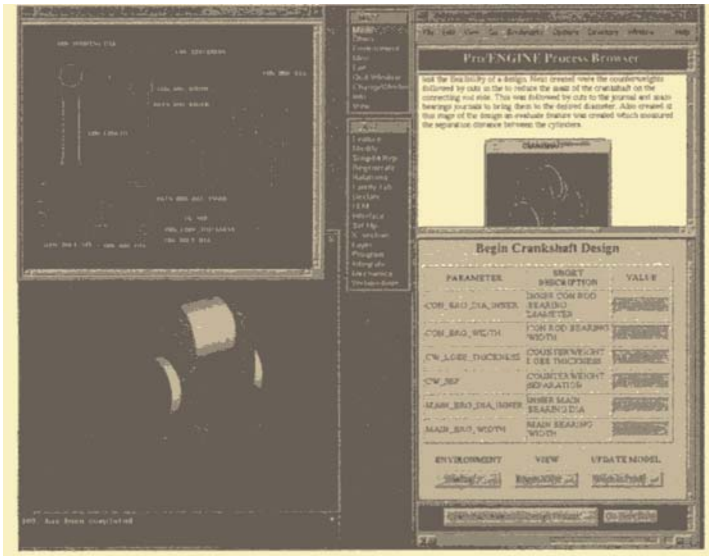


Figure 16.5
PTC Pro/ENGINE Screen Image[33]

The company's focus on the automotive industry was starting to pay off by mid-1997. In prior months, PTC announced substantial orders from BMW, Fiat, Ferrari, Toyota, Hyundai, PSA and Volkswagen. Many of these orders involve the design of automotive engines and transmissions where Pro/ENGINEER's solids modeling capabilities were particularly productive.

When I visited PTC's headquarters in May 1997, the company was preparing to ship the first customer versions of Pro/ENGINE. PTC took a team of 20 application engineers and internal consultants, many with extensive experience designing engines, and had them spend 10 weeks developing the detailed procedures for designing a 280-part engine model They actually took several four-cylinder, 16-valve, inline, double overhead cam engines and physically broke them down to the individual part level.

During the visit, I was told that Pro/ENGINE would sell for $500,000 for a site license for a single major type of engine. This price included a substantial amount of consulting services - perhaps 60% of the cost was expected to be made up of professional services.

**PTC takes a run at the AEC market**

At the June 1996 A/E/C SYSTEMS Conference I was a participant on a keynote panel called "2001, A CAD Odyssey." During my talk, I said that one of the major business developments over the next five years would be PTC's entry into the AEC CAD market. After the session was over, a PTC executive came up to me and asked "What was your source for that statement?" I replied that I had I had no inside knowledge of any PTC plans, that it was just my opinion. He then proceeded to invite me to visit PTC's headquarters as soon as possible, preferably the next week.

At that meeting, I learned that the company was moving in this direction much sooner than I had expected. In fact, PTC was in the process of acquiring a three-

[33] *Computer Aided Design Report*, February 1996, Pg. 1

 

dimensional object-oriented modeling and visualization package developed in England called Reflex from Greenshire License Company for a little over $32 million. This software had been developed by a small group led by Jonathan Ingram and Gerard Gartside who had earlier been involved with other modeling packages including RUCAPS and Sonata.

Sonata had been sold to Alias Research in early 1992 but the marketing of this architectural design package never got off the ground and Alias discontinued sales of it before the year was over. Reflex was fairly new technology that had only been used on a few projects in England but PTC believed that it could be the foundation for a comprehensive process plant and building design product line.[34]

Pro/REFLEX was launched a few months later. Like many other new software packages introduced by PTC, this product had fairly limited capabilities at first with its main purpose to collect feedback from potential users. Pro/REFLEX Release 2.0, a more productive suite of software modules, was released in mid 1967. For the most part, Pro/REFLEX focused on the visualization of architectural models.

A key component of this software was Pro/REFLEX VEL (Virtual Element Language) which could be used to create object oriented modeling elements. These elements could be displayed in different representations depending upon the context of their use, for example as a three-dimensional object in a plant model or as a two-dimensional schematic in a flow diagram. The software was only available on SGI UNIX workstations with a Windows NT version promised for late 1997.

In retrospect, PTC paid far too much for the relatively immature Reflex software and grossly underestimated the effort it would take to create a competitive architectural and plant design product line. This is unfortunate, because at the time, PTC had the financial resources to become a major factor in this market and Intergraph, the largest vendor of plant design software at that time, was going through some difficult changes in its own business.

The company took a charge against income of over $32 million in fiscal 1996 related to this acquisition or basically what it had paid for Reflex. Pro/REFLEX never got off the ground and PTC eventually sold the Reflex technology to a Texas-based design-build firm, The Beck Group, where today it forms the core of DESTINI, or DESign ESTimating Integrated INItiative.[35] A number of the PTC people involved in this effort went on to start Revit, a developer of architectural modeling software subsequently sold to Autodesk.

**PTC and Pro/ENGINEER mature**

In early 1997 PTC launched Pro/ENGINEER Release 18 with significant enhancements to the software's user interface. When Pro/ENGINEER first shipped in 1988, its user interface was state-of-the-art with nearly all interaction done via on-screen menus. For many tasks, the user would select a text item on a menu that would then cause a second menu to appear and sometimes a third. As subsequent software releases were produced, more and more functions were added to this cascading menu scheme and on

[34] One result of this meeting in Waltham, MA was that PTC contracted with me to produce a report describing the technical requirement for a process plant design system, the typical customers for this software and the competitors they would be facing when they entered the market.
[35] http://www.laiserin.com/features/issue16/feature01.php

 

occasion, the individual command the user was looking for might have been six or seven menu levels deep. In most cases, to select alternate commands required the user to step back up this menu chain, one level at a time.

By 1997, competitive systems provided more streamlined user interfaces than did Pro/ENGINEER. PTC recognized the need to change its software to conform with these newer industry techniques and Release 18 represented a start in this direction. According to Dick Harrison, Release 18 represented about 25 percent of what the company planned to do in this area and that Release 19, expected later in 1997, would contain the remainder of the planned changes.

By early 1997, over 25 percent of PTC's sales volume was Windows NT based and in many cases the Windows NT version of the software outperformed the same software running on UNIX workstations. Because of the large portion of its sales volume that was UNIX based, PTC was limited in the extent to which it could adopt Windows user interface standards.

Release 18 also included a new application, Pro/TOOLKIT, that was a significant enhancement to PTC's earlier user development program, Pro/DEVELOP. Pro/TOOLKIT enabled the developers of third party software to write to the Pro/ENGINEER database as well as read that data as was the case with Pro/DEVELOP. At this point, the Internet was staring to take on increased importance and PTC responded with Pro/WEB PUBLISH which enabled Pro/ENGINEER users to generate output that could be viewed with most Web browsers.

**Pro/INTRALINK - A new approach for managing design data**

PTC's customers had been searching for some time for software products that could effectively manage the mountains of information Pro/E produced. Enterprise solutions from companies such as Sherpa and Metaphase involved an excessive amount of custom programming and it was taking as much as four or five years to install some of these systems. By the time they were up and running, the business environment had often changed. Department level solutions such as those offered by Workgroup Technology and Adra, on the other hand, failed to solve the enterprise-wide problems many large companies wanted to address. PTC's own attempts in this area, Pro/PROJECT and Pro/PDM, had also fallen far short of what users were looking for.

Around mid-1995 PTC realized that its customers needed better data management tools than were currently available and if PTC could provide these tools, it would result in substantial incremental business for the company. The first step was to develop an information-oriented programming environment. Known internally as "Delta," this Java-like application programming interface (API) supported over 600 different functions.

PTC used Delta to develop a new client/server data management solution called Pro/INTRALINK which handled traditional product data management (PDM) functions, configuration management and software source control. Introduced in mid-1997, Pro/INTRALINK managed these tasks using a combination of a shared and local databases. The shared database (COMMONSPACE) which was based on Oracle software, was responsible for tracking all design iterations, relationships and configuration information while the local databases (WORKSPACE) enabled each user to work independently. Tools were provided which enable each user's WORKSPACE to access data in the COMMONSPACE and to provide information for updating that shared database. For the most part, Pro/INTRALINK functions were performed transparently to the user. Simply saving a design file updated the WORKSPACE database and closing a design session updated the COMMONSPACE.

When PTC reviewed the status of PDM implementations among its users, one of the issues that came through loud and clear was that these organizations were spending an inordinate amount of effort linking various systems together within their organizations. The company realized that one way out of this dilemma would be to use intranet and Web technology to eliminate most of the effort required to link the desktop Pro/ENGINEER user to enterprise databases and to provide access to this information for others within the organization who typically used a wide variety of PCs and workstations.

Pro/INTRALINK established an operating environment so that whenever a Pro/ENGINEER object was saved, the WORKSPACE database was updated with all relevant information. Part of this process resulted in creating small bitmap images (what we call thumbnails today) of the objects being stored in the WORKSPACE. When users browsed through their WORKSPACE, these bitmaps were displayed nearly instantaneously, greatly facilitating finding what the user was looking for.

The initial implementation of Pro/INTRALINK supported most UNIX workstations and Intel and Digital Alpha versions of Windows NT for both the server and client software. The client software was also supported on Windows 95.[36] One negative was the high cost of this software. Pro/INTRALINK's list price was $5,000 and PTC recommended a copy of the software for each Pro/ENGINEER seat. Obviously, quantity discounts were available and it is unlikely that many companies paid list price for any significant number of licenses.

Unfortunately, software to easily move legacy data from Pro/PDM to Pro/INTRALINK was delayed until well into 1998 and it took some time before Pro/INTRALINK contained all the basic data management functions Pro/PDM had.

**PTC acquires Computervision**

By 1997 it was obvious to PTC and most other people in the industry that data management was taking on an increasingly important role. Walske and Harrison felt that they could jump start PTC's involvement in this growing market by either acquiring or merging with another company. They held some fairly serious discussions with Netherlands-based Baan Company. That summer, Russ Planitzer, Computervision's CEO, met with Walske and Harrison and proposed that PTC consider acquiring the company's CADDS business unit. They countered that it might be better for PTC to acquire all of Computervision.

To put this in perspective, PTC's growth rate in the latter part of 1997 had slowed to 30 percent, about half what it was a year earlier. In the relatively short time span of less than a decade, however, the company had become the dominating vendor in the CAD industry, predominately on the strength of its geometric modeling capabilities. At the time it appeared that traditional software prices were about to come under intense pressure and the industry was starting to consolidate.

Dassault Systemes had acquired SolidWorks and EDS and Intergraph had announced that they were going to merge their mechanical design software activities. *Engineering Automation Report* took the position that PTC needed to broaden its sights

[36] *Engineering Automation Report*, June 1997, Pg. 1

and spend some of its $500 million nest egg on a significant acquisition. The one they selected surprised most industry observers and it turned out to have an even more surprising result for PTC.

In October 1997 I was invited to Computervision's headquarters in Bedford, Massachusetts to preview a new mid-range software package called DesignWave (see Chapter 12). The package was to be introduced at AUTOFACT in Detroit that November and I wrote an article about this new software for the November 1997 issue of *Engineering Automation Report* which was widely distributed at the conference. I was in a fairly crowded briefing room for Computervision's formal introduction of DesignWave at 9:00 AM on November 4th when Wayne George, the company's marketing manager for DesignWave, walked into the room and announced: "And at eight o'clock this morning, Computervision announced that it was being acquired by Parametric Technology Corporation." With that simple statement, he terminated the press conference and all discussion of DesignWave.

PTC agreed to pay $490 million for Computervision, $260 million in stock and the assumption of approximately $230 million of debt. Computervision was close to bankruptcy with its bonds selling at about 50 percent of face value. PTC also assumed Computervision's outstanding lease obligations. This turned out to be more costly to PTC than the company probably expected. In announcing the acquisition, PTC stated that about 500 of Computervision's 1,200 employees would be terminated upon completion of the acquisition.

Computervision's sales had been dropping precipitously but were still in the $350 million range on an annual basis.[37] Paying 1.4 times revenue for a company with an excellent group of customers and some reasonably good technology was probably not unreasonable. The question was how well PTC would integrate the personnel, software products and customer base with its existing operations? Computervision's flagship design software at this point was CADDS 5. By 1997 it was being sold predominately on Sun Microsystems workstations although the company had a large installed base of legacy proprietary systems. Computervision had also picked up a number of other software products over the years including MEDUSA, VersaCAD, Calma's DDM and DIMENSION III, and packages for mapping and electronic design. The software products in the latter two areas had already been sold off by the time PTC got involved.

The primary reason PTC was initially interested in Computervision revolved around the latter company's work with large organizations to implement what it called Electronic Product Definition (EPD). This involved a combination of design and manufacturing software (CADDS 5), assembly management (CAMU or Concurrent Assembly and Mock-Up) and product data management (OPTEGRA) as well as strong consulting support to help make it happen.

In spite of aggressive sales efforts on the part of its competitors, Computervision had managed to retain an impressive list of key EPD accounts including Airbus Industries, Rolls Royce Aircraft Engines Group, Fiat, PSA Peugeot Citroen, General

[37] The acquisition of Computervision was accounted for as a "pooling of interest." As a result, PTC subsequently combined CV's historical financial results with its own which somewhat distorts the company's reported results. For the purpose of this book, I have chosen to use the company's financial results as they were originally reported since this provides a clearer picture of PTC's growth, especially during the 1990s.

Electric, and Raytheon. PTC had long wanted to duplicate what Computervision had accomplished with these major accounts. The company had particularly struggled in the PDM area and adding Computervision resources was expected to be particularly useful in building its large account business. Optegra was expected to provide an enterprise PDM capability to complement the department-level software PTC was currently selling.

CADDS 5 differed from Pro/ENGINEER in that it supported hybrid modeling (wireframe and surfaces and well as solids) and explicit design in addition to parametric design. It was good software that had not received the attention it perhaps deserved because Computervision's financial problems seemed to overwhelm technical issues in the minds of prospects. In the short term, PTC planed to continue CADDS 5 development and stated that they might even expand the effort. The company also planed to develop a direct translator between CADDS 5 and Pro/ENGINEER. At the time, my observation was that within a few years, the two product lines would begin to share technology and perhaps even start to blend together as a single product suite. This is what happened a few years later when Unigraphics Solutions acquired SDRC and its I-DEAS product line.

One major issue was whether PTC would follow through with the release of the recently announced DesignWave software since it would compete directly with PTC's PT/Products mid-range CAD/CAM suite. Another unknown at the time of the announcement was what would happen with new Internet-oriented PDM software being developed by a company called Windchill Technology which CV had been funding. The latter organization, located in Minneapolis, was founded in October 1996 by ex-Metaphase personnel including Jim Heppleman. Windchill would eventually form the basis of a new generation of PDM tools for both Computervision and PTC users.

My conclusion at the time was that if someone like PTC had not come along, it was questionable if Computervision would have been able to survive on its own. Once some organizational redundancies were eliminated, the acquisition was expected to be a profitable move for PTC. I thought it would be particularly beneficial for customers who were using both CADDS 5 and Pro/ENGINEER or companies that were still using CADDS 4X and had been reluctant to upgrade or switch to a new vendor. Between the two companies, they had over 190,000 seats of high-end design software installed at over 20,000 customers. It was an impressive presence in this rapidly evolving industry. The acquisition of Computervision was completed on January 12, 1998.

**Windchill changes PTC direction**

By early 1998, some aspects of PTC's acquisition of Computervision were starting to take shape. For PTC to regain its sales growth momentum it was becoming increasingly obvious that the company had to become the primary engineering and manufacturing technology provider to large global enterprises, particularly those in the automotive and aircraft industries. Computervision provided entry to a number of large accounts such as Airbus Industries[38], enabling PTC to compete more effectively with the other global enterprise vendors including Unigraphics, Dassault and SDRC.

[38] In 2006, the French portion of Airbus was still using CADDS 5 software to design about 75 percent of the Airbus 380. The German operation was using CATIA V4 for the balance of the aircraft. In a conversation with Dick Harrison in July 2006, he stated that one of the reasons Airbus was having problems with the 380 was the lack of mockup software in Germany as compared to the former Computervision software the company was using in France.

 

To pursue this market, PTC planed to establish a large account sales and support organization based on a similar setup that has been particularly successful at Computervision. This group was assigned the task of focusing on the top 20 accounts the combined company then had and it reported directly to PTC's top management.

In a financial conference call in January 1998, the company made it obvious that the most significant development expected at PTC during the next several years would be increased emphasis on Product Information Management (PIM) solutions.[39] In the short term, Pro/ENGINEER users would be sold Pro/INTRALINK while the CADDS 5 users would continue to use Optegra for these applications. PTC already was talking about tying this all together with new technology being developed by Windchill. Steve Walske described Windchill as "a diamond in the rough."

Prior to completion of the acquisition, Jim Heppleman visited PTC and described to Harrison and others Windchill's development strategy. They became intrigued with the ideas Heppleman was proposing and subsequently bought the portion of the company not owned by Computervision from Windchill's founders and employees and it became a subsidiary of PTC. Walske's reaction was "its better to be lucky than smart."

Key Windchill developers including John Gibson, Jim Schoenberg and John Houston stayed with the group while Jim Heppleman, Windchill's chief technical officer, became a senior vice president at PTC. Jim Baum, a senior vice president who had been heading up PTC's PIM activity, retained responsibility for Pro/INTRALINK and the data management elements of Computervision's Optegra line. Wayne Collier, writing in *Engineering Automation Report* commented: "The full price Parametric paid for Computervision seems validated: besides the CV customer base, it has acquired a technical jewel in Windchill."[40]

Two Windchill products were then in development. NetFactor was a broad Web-based Java software environment with vaulting, document management, life cycle management and workflow capabilities. Product Center was a series of vertical applications such as change control and configuration management. Computervision had been beta testing this software at some of its major accounts prior to the completion of the acquisition. PTC planed to add some of its customers to the beta program and to release the software in June 1998.

By itself, the Windchill software was an interesting development. What was even more interesting, however, was PTC's description of this technology as laying the foundation for the company to potentially move into the Enterprise Resource Planning (ERP) market. According to *Engineering Automation Report*:

> "This is an intriguing thought. Most ERP vendors, such as SAP, Oracle and J. D. Edwards, approach ERP from a financial perspective. PTC, on the other hand, will come at it from a product design and PDM perspective."[41]

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[39] In 1999, PTC began using the term Collaborative Product Commerce or CPC. Around 2001 the term changed to Collaborative Product Development or CPD. This was short lived and in 2002, PTC, as other industry vendors already had, began using PLM which stands for Product Lifecycle Management.

[40] Collier, Wayne, "Parametric Lays Siege to the ERP Fortress," *Engineering Automation Report*, March 1998, Pg. 13

[41] *Engineering Automation Report*, February 1998, Pg. 5

PTC executives felt that over the next several years the company's business could split one-third CAD and two-thirds information management. Walske repeatedly stated that the mechanical CAD business was becoming a lower-growth industry and that the future was in managing design information, not just in creating it. One example of the new emphasis the company placed on this area was the setting up of a separate sales force to promote information management software products and services. Initially, it had about 30 dedicated sales representatives with 60 to 75 planned by the end of mid-1998. Several months later, at the Kalthoff International User Forum in San Diego, PTC marketing personnel were talking in the context that the ERP market was 30 times the size of the PDM market and more than four times the size of the entire CAD industry.[42]

During the conference call mentioned above, Walske was asked what would happen with Computervision's new DesignWave mid-range package which had been introduced the same day the acquisition was announced. Walske reiterated his previously stated concern that he was not convinced that there was a substantial mid-range market.[43] In spite of this concern, Walske planned to provide increased funding for the development and marketing of DesignWave and give the team responsible for it an opportunity to prove him wrong.[44]

In the first quarter of calendar 1998, PTC reported revenues of $264 million, up just 6 percent from the prior year's $250 million. Earlier results were restated to include Computervision's numbers. It was immediately obvious that although PTC was seeing a jump in revenues due to the acquisition, Computervision's business was continuing to decline, offsetting gains in the sale of Pro/ENGINEER.[45] In spite of this, PTC was now the first billion dollar CAD software firm.[46]

**The future looks bright -temporarily**

Release 19 marked a significant change in Pro/ENGINEER development strategy. Previously, PTC promoted the fact that it was able to grind out a new release of software every six months. This pace slowed down with Release 19 and the company switched to a ten month upgrade cycle with beta test sites receiving new software about six months prior to its general release. While this was less frequent than before, it was still better than what most competitors were able to do. Much of the user interface change originally scheduled for Release 19, however, were postponed to Release 20.

One area where PTC was moving slowly was incorporating Pro/DESIGNER into the Pro/ENGINEER product suite. Three years after acquiring CDRS from E&S, this software was still being sold as a separate product with its own icon-oriented menu structure and separate database. While surface geometry could easily move from Pro/DESIGNER to Pro/ENGINEER, if a surface geometry change needed to be made, that had to be done in Pro/DESIGNER and the data translation repeated. Workable but awkward.

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[42] *Engineering Automation Report*, April 1998, Pg. 9
[43] To some extent this sounded similar to statements attributed to Ken Olsen, CEO of Digital Equipment Corporation, who described the PC as a passing fad.
[44] *Engineering Automation Report*, February 1998, Pg. 5
[45] *Engineering Automation Report*, May 1998, Pg. 15
[46] Intergraph was also a billion dollar company but a significant portion of its revenue was from the sale of computer hardware.

 

By mid-1998, PTC seemed to be doing all the right things necessary to take the company to the next level of technical and business accomplishment. In general, the integration of Computervision into PTC's operations was going well with a number of senior Computervision employees taking on comparable rolls at the combined company. Fairly quickly, PTC decided not to run the Computervision operation as a separate business entity but to combine it all into a single integrated organization.

John Stuart, PTC's senior vice president of marketing stressed to *Engineering Automation Report* that former Computervision products such as Medusa and CADDS 5 would continued to be actively supported and enhanced. The plan was good but the details were in its execution and as described below, things did not always work out as the company expected. PTC was on target to do about $1.16 billion during fiscal 1998. That made PTC the largest company in the CAD industry and the fifth largest independent software firm in the world in terms of revenue. The company now had over 4,700 employees.

PTC was far from finished making acquisitions. The next business entity the company was interested in turned out to be the ICEM Technology division of Control Data Systems which it purchased for $40.6 million in cash. This Frankfurt Germany-based operation developed and marketed some excellent surface geometry and reverse engineering software (ICEM Surf) used extensively in the automotive industry at accounts such as Audi, BMW, Ford and General Motors.

The challenge for PTC was to take the best of the surface geometry capabilities in Pro/ENGINEER, Pro/DESIGNER (ex-CDRS), CADDS 5 and ICEM and blend them together. ICEM never seemed to fit into the company's MCAD business model and in mid 2002 the business, which was still doing a little over $11 million annually, was sold to its management for $10.6 million or one times revenue.

Windchill was where most of the excitement was in mid-1998. To put this interest in perspective one needs to realize that most of the early commercial PDM and ERP solutions had been implemented on mainframes or minicomputers. This was followed by a switch to client/server computing where a great deal of effort went into providing software that would run on a variety of client and server platforms: PCs, UNIX, Macintosh, etc. Most of these systems were difficult to implement due in part to customers constantly changing the platforms they wanted supported, especially client (desktop) machines. Many users ended up spending more on implementation services than on the software itself. One result was that numerous companies never got out of the pilot stage and those who did, found their systems difficult to adapt to changing business requirements.

One indication of the extent to which PTC's management was getting carried away with Windchill in mid-1998 was a statement by Walske that in three years (i.e. 2001) the PDM area would generate two-thirds of PTC's revenue.[47] It turned out to be more like 23 percent, a number that has only increased in the succeeding years to about 35 percent.

When the Internet and the World Wide Web became important technologies, most of the vendors of existing PDM and ERP systems adapted their products to the new environment with varying degrees of success. What set Windchill apart from nearly all its competitors at the time was that this software had been implemented from the start on the

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[47] Kempfer, Lisa, *Computer-Aided Engineering*, June 1998, Pg. 28

 

basis that it would take advantage of the new generation of Web-based software tools and concepts. PTC promoted the idea that this approach was far more effective than trying to add these new concepts to legacy information management solutions. The difference was that Windchill was Web-centric, not simply Web-enabled.

The overall Windchill concept used a three-tier architecture where the user communicated with the system through a standard Web browser such as Internet Explorer or Netscape Navigator. This led to an application layer which typically consisted of a standard Web server such as Microsoft Internet Information Server or Netscape Enterprise Server. The application layer fed HTML pages to the user's Web browser or downloaded Java applets to accomplish predefined functions such filling in a form or routing a document to another team member. The third tier consisted of the data itself which was stored in an object-enabled relational database such as Oracle 8.

The original NetFactor software module evolved into a product PTC called Windchill Foundation. It could best be described as the object-oriented glue that tied the three-tier architecture together and provided the starting point for either PTC or user developed applications. An enterprise license for Windchill Foundation was $250,000. The second building block was the Windchill Information Modeler, a $10,000 program that provided an application development environment. PTC also offered two applications, Windchill Document Manager priced at $800 per named user and Windchill Configuration Manager priced at $900 per named user. PTC claimed at the time that it had closed million dollar deals with Airbus and Sun Microsystems and had over 20 prospects for similar size deals.

It still was not clear how aggressively PTC planned to pursue the ERP market. Less than six months after first promoting that idea, the company seemed to be backing off its initial stance. I was still enthusiastic about the idea and wrote:

> "PTC comes to the ERP marketplace with an engineering design and product manufacturing mindset. The company appreciates that a bill-of-material for a design engineer looks a lot different than what it does to manufacturing or purchasing. A design-centric ERP solution will provide customers with a choice that they really do not have today. It might not be for everyone, but PTC's strategy will create a broader range of choices for the user community."[48]

Meanwhile, DesignWave remained in the company's product line and appeared to be getting more development and marketing support than it probably would have received under Computervision. PTC set up a separate business unit for mid-range systems with Jon Stevenson, who was the driving force behind DesignWave, as the senior vice president for this group, reporting directly to Dick Harrison. This business unit was also given marketing responsibility for the existing PT/MODELER package, over 15,000 copies of which had been sold by mid-1998. DesignWave was priced at $3,495 as compared to $2,995 for PT/MODELER.

Meanwhile, PTC had not forgotten Pro/ENGINEER. Release 20 went into pre-production testing in mid-1998 with a substantially new user interface that utilized a new

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[48] *Engineering Automation Report*, July 1998, Pg. 6

menu bar and other features users had become familiar with through their use of Microsoft’s various Windows operating systems. Previously, PTC had developed UNIX

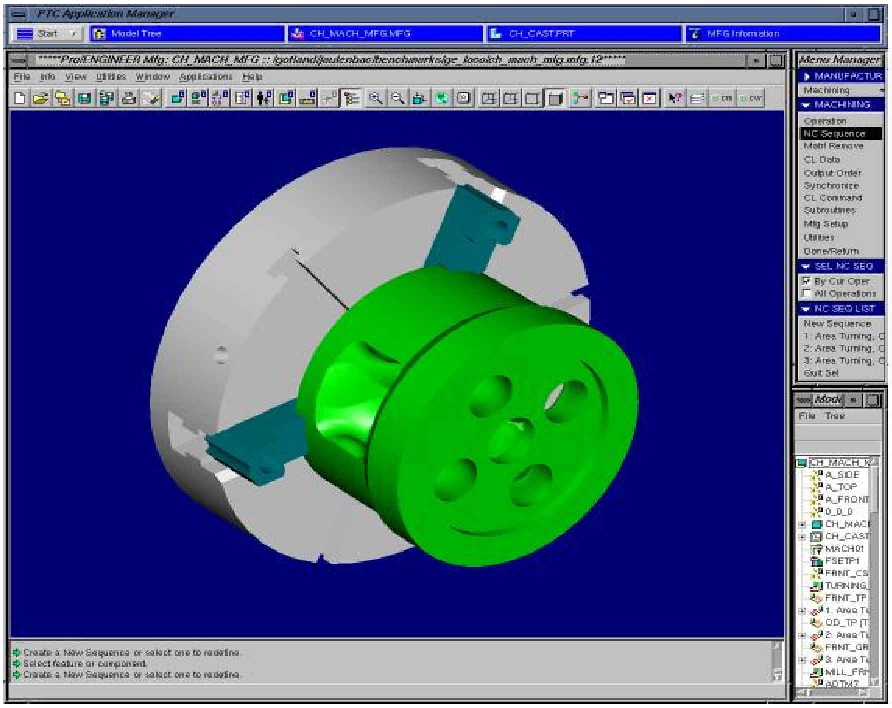


Figure 16.6
Pro/ENGINEER Release 20 with new user interface and updated sketching capability

versions of its software that were then ported to Windows but still looked like UNIX programs. With Release 20, this methodology switched and now Pro/ENGINEER looked more like a Windows program and that version was implemented on the UNIX workstations the company still supported.

Release 20 also incorporated a new sketcher called Intent Manager which facilitated the definition of constrained geometry. As the user sketched a 2D profile, the software automatically determined constraints and dimensions and displayed these on the profile. Another new capability was the ability to append notes to 3D models of parts and assemblies. When the user scaled or rotated the model, these notes retained their original orientation and were always visible to the user.[49]

**A bump in the night**

On July 1, 1998, PTC announced preliminary results for its third fiscal quarter ending June 30th that severely disappointed stockholders. For the first time in the company’s history, quarterly revenues actually decreased compared to the prior year, from $249 million in 1997 to $245 million in 1998.[50] The company claimed that much of the shortfall was due to the delay in receiving a number of very large orders it had expected. A number of these did come in shortly after the quarter closed including

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[49] *Engineering Automation Report*, July 1998, Pg. 6
[50] These results included Computervision’s revenue prior to the acquisition.

 

several from long-time Computervision customers including Rolls-Royce Aero Engine which ordered $2.7 million of Pro/ENGINEER and Windchill software.

The next day, PTC's stock dropped 35 percent in value and before the month was over, it was down nearly 60 percent to $14.19 per share. This was the start of a long painful part of PTC's history, a phase it is still recovering from.

There were a number of factors impacting the CAD industry and PTC in particular in mid-1998:

- Mid-range systems had developed a level of geometric modeling and drawing productivity in just a few years that had taken PTC a decade to achieve. Many potential customers were satisfied with the capabilities these lower cost systems offered.
- Windows NT was becoming the technical operating system of choice. Over 50 percent of Pro/ENGINEER shipments were now for this version of its software. When someone paid just $4,000 to $6,000 for a high-end PC with excellent graphics, they were reluctant to shell out nearly $20,000 for software.
- Several years earlier, competitive products such as CATIA, Unigraphics and I-DEAS could not do what Pro/ENGINEER could. By mid-1998, these other packages had improved significantly and in some cases had progressed farther than Pro/ENGINEER. PTC had probably kept a lid on its R&D investment for far to long. The company's software was beginning to look somewhat out of date, especially in regards to its Windows based systems which had a UNIX look-and-feel until Release 20.
- Companies were increasingly focused on information management, not just design creation. IT solutions were a harder sell that took much longer to consummate. Unfortunately, Windchill was still a collection of technologies that required far too much effort on the part of customers to install and make part of the mainstream of their operations.

It was no surprise when PTC announced that it was restructuring its 900-person sales force. After acquiring Computervision, it became apparent to PTC that its historical "one size fits all" sales management model would no longer work, particularly for large strategic accounts. As a result, the company switched to a four tier sales structure, each with its own management organization.

**Major Accounts –** A separate sales organization with about 100 account managers was set up to pursue business with the company's 300 largest accounts and potential prospects. The Major Accounts sales people were responsible for all PTC products at these accounts.

**Primary Accounts –** The bulk of the sales force continued to be assigned territory responsibility for selling Pro/ENGINEER and related software products and services. Explicitly excluded, however, was the Windchill product line.

**Windchill –** PTC continued to focus on building a sales and support staff specifically chartered to go after Windchill PLM business, both within the existing Pro/ENGINEER user base and at accounts that were using competitive design systems. A typical Pro/ENGINEER user had to deal with two sales people, one handling Pro/ENGINEER and the other Windchill.

**Small Accounts –** When PTC first started, a high percentage of its sales was through various types of resellers. By 1996, this had dropped to 10% of the company's revenue and, as noted earlier, PTC changed its reseller agreements such that these companies were no longer able to sell Pro/ENGINEER but were limited to PT/Modeler. The one exception was Rand Technologies which continued selling Pro/ENGINEER to its existing customers. In a major move, PTC and Rand signed a multi-year agreement under which Rand became the master distributor for all PTC products except Windchill in North America and Europe for all companies with less than $10 million in revenues.

*Engineering Automation Report* commented:

> "… the agreement with Rand is significant in that a single monolithic sales organization typically has problems selling individual copies of different software products to small companies while at the same time trying to develop meaningful long-term relationships with large global enterprises. Rand, itself, will use an additional tier of resellers or 'business partners' as they refer to these smaller vendors. PTC sales personnel who had been targeting smaller accounts will be reassigned to the other three organizations while we expect that Rand will undertake a substantial staff expansion in coming months. In addition, the 100 or so independent resellers who have been selling PT/Modeler and DesignWave will continue to do so, but it is still unclear as to how much effort PTC will put into expanding this group."[51]

One result of the restructuring was that PTC laid off over 300 people from its sales and marketing organization during the first half of fiscal 1999. On the other hand, the company began expanding its professional services organization (PSO). By the end of fiscal 1999 the company had nearly 5,000 employees.

This was far from the last time PTC would reorganize its sales organization as it strove to find the combination that would get it back on a growth track. The agreement with Rand was changed several times. First, the limit was increased to $50 million, then the exclusivity was removed and Rand was authorized to sell to all businesses except PTC's 200 largest accounts. The relationship between the two companies continued to be rocky and by 2003, Rand was just about out of the business of reselling Pro/ENGINEER and was becoming an affiliate of Dassault Systemes reselling CATIA.

## Getting back on track

One of the first steps PTC took to regain its earlier growth momentum was to drop the PT/Products software including PT/Modeler and to replace them with a product called Pro/ENGINEER-Foundation. For just $5,995, a customer received full-function Pro/ENGINEER software capable of part and assembly design, drawing production, bill-of-material generation, photorealistic visualization and data translation. Unlike PT/Products, customers could upgrade the Foundation package with any of PTC's other application programs. Existing PT/Products users were allowed to upgrade to Foundation or DesignWave at no cost.[52]

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[51] *Engineering Automation Report*, August 1998, Pg. 1
[52] *Engineering Automation Report*, September 1998, Pg. 10

No sooner had the dust settled on the Foundation announcement then PTC launched Pro/DESKTOP, built on DesignWave but with an internal model topology similar to Pro/ENGINEER. This was intended to enable better data movement between the two packages. The vehicle for doing this was called the Associative Technology Bus (ATB). It enabled the two packages to share geometry and topology without having to translate models from one database to another. Pro/DESKTOP, priced at $3,495 per license, could open Pro/ENGINEER files directly and use these models as if they were created in Pro/DESKTOP. The plan was that in early 1999 Pro/ENGINEER users would be able to do the same thing with Pro/DESKTOP and CADDS 5 models. DesignWave as such, ceased to be product.[53]

In early 1999, PTC's Windchill strategy was becoming somewhat clearer. The company was beginning to appreciate the extent to which Windchill customers needed technical and business management support in order to use Windchill effectively. PTC had inherited a substantial consulting services organization when it acquired Computervision, but this group was insufficient to meet the total demand for such services. The company began working with outside management consulting firms to provide these services, initially Computer Sciences Corporation, Price-Waterhouse and Anderson Consulting (Subsequently renamed Accenture) .

PTC's Windchill group recognized three principals that influenced the company's broad concept of PDM:

- First was the concept that within a large organization, a single data structure or schema could not meet the requirements of all the individual groups in the enterprise.
- The second principal was that an enterprise-wide information system could best be implemented using Internet and Web standards.
- The third principal was that most companies did not want to replace their existing data management solutions. Instead they wanted to implement Windchill as an umbrella technology, install enterprise-wide applications, and then link existing commercial and custom applications to the Windchill infrastructure.

This was a complex message that PTC had a hard time communicating to potential customers, partially because it was an enterprise-wide IT message and most of PTC's sales personnel were more comfortable talking about product design to engineering management. In spite of this, by late 1998 there were already 50 pilot Windchill projects. One major problem was getting companies to move from the pilot stage to full enterprise-wide rollout. A subtle change was going on in the development associated with Windchill in that an increasing amount of resource was being applied to the development of specific applications such as product configuration, manufacturing process planning and supplier management. Also, the company was talking less about pursuing the ERP market and more about interfacing to leading ERP packages.[54]

**Acquisition pace continues**

PTC was not finished making acquisitions. In October 1998 the company acquired InPart Design, the developer of DesignSuite, a web-based information service

[53] *Engineering Automation Report*, December 1998, Pg. 10
[54] *Engineering Automation Report*, January 1999, Pg. 6

intended to be a repository of three-dimensional mechanical part data. InPart created its library of component data using Pro/ENGINEER and distributed this information in Pro/ENGINEER, IGES, STEP and AutoCAD DXF formats. Customers used a proprietary client program to retrieve component outlines that could be incorporated into CAD assembly designs. PTC paid for InPart with 600,000 shares of stock worth about $38 million at the time.

On January 21, 1999 the company announced plans to acquire the Division Group, a vendor of visualization, simulation and integration tools for approximately $48 million in stock and cash. This was about 4.5 times Division's then current revenues. Based in Bristol UK, Division originally developed and marketed toolkits that facilitated the implementation of virtual reality-like visualization software. In the two years prior to the acquisition, the company changed its focus and began selling actual applications such as dV/MockUp, a virtual prototype and visualization package.

In September 1998, Division had announced the planned acquisition of ObjectLogic, a small software firm in San Diego. This deal closed in March 1999. PTC subsequently offered that company's primary application as dV/ProductView. This latter package enabled users to view, markup, and circulate product data generated on a wide range of CAD systems with conventional Web browsers.

The press release sent out by PTC mentioned the future opportunities the company saw in integrating Division's applications with PTC's Windchill technology. *Engineering Automation Report* commented:

> "We also see an interesting opportunity that was not mentioned. That is the integration of dV/MockUp and dV/ObjectLogic with the Concurrent Assembly and MockUp (CAMU) software PTC obtained through its acquisition of Computervision early last year. We have not heard much about CAMU from PTC recently, but it was one of CV's best jewels. Between the Division software, Windchill, and CAMU, PTC has the basic building blocks to offer customers an integrated assembly management solution that is independent of the CAD system used to create individual part models."

This never happened the way I expected.[55]

The third acquisition was auxilium, a vendor of Web-based information management development tools used to integrate legacy databases and application programs. The price for this deal which was also completed in March 1999 was nearly $102 million.

**Windchill and Pro/ENGINEER continue to evolve**

By the spring of 1999 PTC claimed to have 200 Windchill installations of which 10 to 15 were considered production sites. Later that year the company began comparing Windchill revenue during the first four quarters it was on the market to Pro/ENGINEER revenues during its first four <u>years</u>. During its fourth year Pro/ENGINEER generated $45 million in sales while Windchill generated $40 million in its fourth quarter.

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[55] *Engineering Automation Report*, February 1999, Pg. 5

PTC changed its naming of Pro/ENGINEER releases with what was expected to be Release 21. Instead the company decided to switch to a year nomenclature and the software became Pro/ENGINEER 2000i where the "i" stood for "interoperable." The most significant aspect of 2000i was a new technology called "behavior modeling." Sold as the Behavioral Modeler Extension it was priced at $4,995.

As an example of behavioral modeling, if the user wanted a part to have a set volume and needed to minimize its surface area, the user would define which parameters (dimensions) could be changed, the range that they could be changed in, and the number of iterations permitted. The system would then iteratively change the model to meet the criteria that were to be minimized or maximized. Although this might have taken several hours on a 1999-era workstation, manual trial and error could have taken days.[56]

Other 2000i enhancements included an expanded version of the Associated Topology Bus or ATB. As initially developed, it enable Pro/ENGINEER users to import geometry from older legacy systems such as CADDS 5 and CATIA V4. This software imported the basic geometry into Pro/ENGINEER but not feature definitions and constraints. The geometry could subsequently be incorporated into Pro/ENGINEER models and manipulated as if that software had created it. If the part was subsequently changed in the originating systems, those changes would flow through to the new Pro/ENGINEER model.

Pro/ENGINEER 2000i was followed up a few months later with Pro/MECHANICA 2000i. Since being acquired by PTC, the Pro/MECHANICA software was associative with Pro/ENGINEER models but the new 2000i version operated directly on Pro/ENGINEER models instead of converting them into its own format. This was accomplished using PTC's ATB which was also used to communicate with other PTC i-series programs.[57]

One change in 2000i that caused other software firms substantial grief was the change from ASCII coded data in Pro/ENGINEER files to binary coded data. This reduced the size of most Pro/ENGINEER files by about 50 percent but made it much more difficult for other software packages to read the data unless they used PTC supported application programming interfaces. One problem with the latter approach was that it required an active Pro/ENGINEER license in order to use the software.[58]

About this point in time, one had to wonder if PTC simply had too many products on its plate as the result of all the acquisitions it had made during the prior several years. On top of that issue, Windchill activity was changing the nature of the company. By mid-1999, PTC had over 800 people dedicated to Windchill, nearly 300 of whom were developers. This is not to say that PTC was ignoring other products. The ICEM Technologies subsidiary, which PTC had acquired in 1998, was now responsible for the CDRS and 3D PAINT packages also. In August 1999 new versions of the ICEM, CDRS and 3D PAINT software were released that had improved capabilities for transferring surface data to and from Pro/ENGINEER 2000i. One reason for operating ICEM Technologies as a separate business was that there were many users of this software who used CAD tools from vendors other than PTC and this level of independence was necessary in order to maintain that revenue flow.

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[56] *Engineering Automation Report*, April 1999, Pg. 4
[57] *Engineering Automation Report*, June 1999, Pg. 9
[58] *Computer Aided Design Report*, October 1999, Pg. 9

The new ICEM Technologies software releases also used the 2000i nomenclature as did new software from Division. This included new versions of DIVISION Product View and DIVISION MockUp (previously called dv/Reality). It appeared as if PTC was planning on competing with Engineering Animation Incorporated for the high end visualization business in the CAD market. Towards the end of 1999, PTC repositioned Pro/DESKTOP once again, this time as a conceptual design front-end to Pro/ENGINEER. Priced at $3,495, PTC claimed to be selling several thousand units per quarter.

By the last quarter of fiscal 1999, PTC seemed to be getting its growth back on track. Revenue was up 12 percent compared to the prior year to $280 million with earnings of over $50 million before consideration of special charges associated with the company's acquisition spree. This would turn out to be the company's high water mark. During the last quarter of calendar 1999, PTC's overall revenues slipped once again, down 4 percent compared to the prior year to $239 million. Windchill-related revenue was over $38 million compared to just $5 million for the same quarter a year earlier. This meant that revenue for Pro/ENGINEER and other design-related packages was just $200 million compared to about $245 million the year before.

There were probably several reasons why PTC was struggling with the MCAD portion of its business:

- Competitive mid-range solutions such as SolidWorks and Solid Edge could now handle much of the work that previously required heavy duty software such as Pro/ENGINEER.
- The company's constant reorganizing of its field sales force had adversely impacted PTC's ability to close business. The size of the company's direct sales force was about 10% below where management wanted it to be at the end of 1999.
- Sales to smaller customers through Rand Technologies meant that PTC received less revenue per sale.
- Finally, the company's focus on Windchill may have taken management's eye off the CAD market.[59]

The problems with the MCAD market did not seem to really bother PTC's management as it focused much of its resources on its Windchill activity. As clearly stated in the company's 1999 10-K Report:

> "We are incurring expenses that would support revenues in excess of current levels in order to implement our strategic initiatives, particularly as they relate to our Windchill solutions. Although these expense levels have adversely affected net income, we continue to believe that these initiatives will provide a foundation for future growth."[60]

**The 21st century - A changing business environment**

In early 2000, PTC stopped referring to itself as Parametric Technology Corporation and began simply calling itself PTC, although legally it was and still is

[59] *Engineering Automation Report*, January 2000, Pg. 15
[60] PTC 1999 10-K Report, Pg. 10

Parametric Technology Corporation. Marketing material also starting referring to PTC as the "Product Development Company."[61] For the next several years, the company produced a series of Pro/ENGINEER releases that made product design easier and more flexible and speeded up assembly modeling as well as a continuous stream of new Windchill software modules.

Eleven months after Pro/ENGINEER 2000i was released, PTC launched 2000i$^2$ with a new Windows-compatible user interface. Rather than making its Windows software look like the UNIX version of Pro/ENGINEER, PTC made its UNIX-based software look similar to the Windows implementation, a fairly strong statement regarding what the company expected the majority of its customers to be using in the future. PTC also change the sequence in how operations were executed.

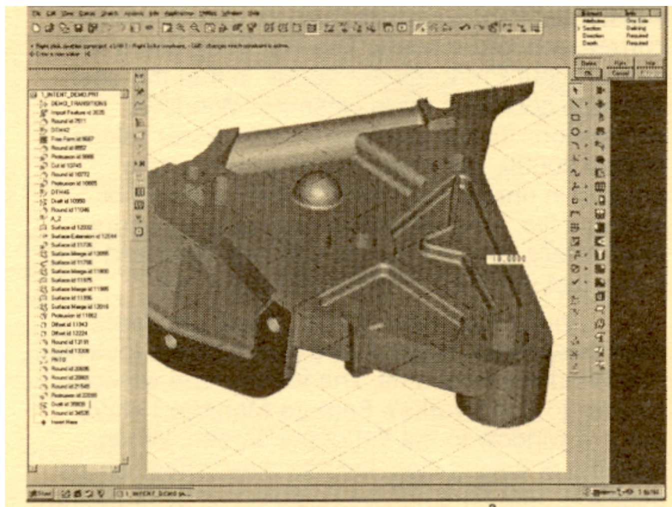

Figure 16.7
Pro/Engineer 2000i$^2$ with Windows-like User Interface

With previous versions of Pro/ENGINEER users selected an operation and then selected the geometry on which that operation would be executed. Starting with 2000 i$^2$, the sequence was reversed. Geometry was selected and then the operations to be applied to that geometry were initiated, much like other Windows applications. This release also incorporated substantial improvements in how sequences of features were regenerated as well as how geometry was created and edited. The *Computer Aided Design Report* was impressed with this release but felt that many of the improvements it contained should have been done earlier.

> "It's unfortunate for PTC and Pro/E users that the train didn't leave sooner. Had Pro/Engineer's developers started working in 1994 on the kinds of improvements made to Pro/Engineer 2000i$^2$, its share of the CAD market would not now be declining and companies such as SolidWorks and Unigraphics Solutions would not be winning as much business at

[61] In 2002 the new marketing term was "Product First." The theme was that "great products make great companies."

 

PTC's expense. Moreover, 11 months between releases is too long in a world where competitors are turning out lists of improvements every six months."[62]

In the first quarter of the new decade, PTC's revenues slid 14 percent to $227 million and earnings on an operating basis were just about nonexistent. Other companies were not having similar problems. Autodesk's quarterly revenues grew by 14 percent during roughly the same period to $223 million. The stock market did not treat PTC's financial results kindly. During April 2000 the company's stock which had climbed back to $25.46 per share dropped to just $8.25. This coincided with the start of the massive decline in high tech stocks as the NASDAQ index slid from over 5100 in March 2000 to a low of 1100 in October 2002.

In June 2000, I wrote a front page article in *Engineering Automation Report* titled "PTC Faces the Biggest Challenges in its History." In addition to the issues mentioned above, I pointed out several other problems the company was facing.

- Large enterprises often considered Pro/ENGINEER to be under-powered for their needs when compared to CATIA or Unigraphics. This kept the company from gaining a more significant presence in large global companies.
- The acquisition of Computervision, Division, CDRS and other companies left PTC with a boatload of product integration issues. Resolving these problems probably took resources away from addressing some mainstream product and marketing issues.
- Although Pro/ENGINEER was credited by many with revolutionizing mechanical design twelve years earlier, some observers considered it to be old technology by 2000. In particular, the lack of surface defined modeling, what is typically called hybrid modeling, was seen as a weakness by automotive and aircraft manufacturers.[63]

The company soon took several steps to get things turned around. Dick Harrison replaced Steve Walske as CEO in April 2000 although Walske stayed on as chairman and "chief business strategist." This didn't last very long and Walske severed all management connections with PTC in June and was replaced as chairman by Noel Pasternak, a partner in a Boston law firm who has been associated with the company since its start. The company was restructured into three business units:

- Windchill and Web-based collaborative solutions under Jim Baum who previously was responsible for product development
- MCAD products and flexible engineering solutions under Jon Stevenson who had joined PTC with the Computervision acquisition
- Netmarkets, a new dot com initiative headed up jointly by Jim Heppelmann and Stacy Lawson. Lawson had joined PTC when it acquired the company she had founded, InPart.

[62] *Computer Aided Design Report*, April 2000, Pg. 5
[63] *Engineering Automation Report*, June 2000, Pg. 1

At this point in early 2000, nearly everyone was still enamored with the Internet and the company was fond of quoting market research statistics that claimed Business-to-Business Internet activity would be as much as $1.8 trillion by 2003.[64]

In the June 2000 article I asked:

> "The final question is whether Pro/ENGINEER still a competitive product. Ray Kurland, the president of TechniCom and a well respected industry analyst recently took a hard look at Pro/ENGINEER 2000i$^2$. His comments were that PTC had significantly improved ease of use, top-down design and sketching which now has good auto-constraint capabilities. Kurland particular liked the fact that the software's Behavioral Modeling function could now handle multiple objectives. It also can output data directly to an Excel spreadsheet when used on a Windows system. Engineers who understand how to work with Excel equations can perform some interesting tasks with the combination of the two programs.
>
> "PTC is planning to incorporate the CDRS surface modeling software directly in the next release of Pro/ENGINEER. This will resolve perhaps the most serious problem facing PTC in pursuing automotive accounts. Overall, Kurland feels that Pro/ENGINEER is a very competitive product today and that the company just needs to get its sales act together."[65]

As mentioned earlier, one of the major reasons PTC acquired Computervision was to gain access to its customer base of large companies. On June 1, 2000, PTC announced one of the largest contracts it ever received, a $22 million order from Airbus for both mechanical design and Windchill software and services. Airbus had long been a key Computervision customer. In fact Computervision at one time had nearly 200 people in its Paris office, many of them assigned to support Airbus.[66]

By mid-2000, PTC had nearly 400 Windchill customers, of which 80 percent were either Pro/ENGINEER or CADDS 5 users. For fiscal 2000, PTC reported revenues of about $928 million, nearly $130 or 12 percent less than the prior year and the company had a loss of $4 million for the year compared to profits of nearly $120 million the year before.

The new three part organization structure announced earlier in the year didn't last until the end of the year. By November, PTC had combined the basic Windchill operation with the Netmarkets initiative into a single division with Jim Heppelmann in charge. Barry Cohen, who like Jon Stevenson had come to PTC as a result of the Computervision acquisition, became an executive vice president responsible for marketing.

In March 2001, PTC announce Granite One[67], a toolkit that provided third party software firms and customers access to the Pro/ENGINEER database. When initially announced, the perception was that Granite One was a geometric modeling kernel similar to Parasolid and ACIS. In reality, its primary use has been to extract data from the

[64] PTC Fiscal 2000 Annual Report, Pg. 4
[65] *Engineering Automation Report*, June 2000, Pg. 1
[66] *Engineering Automation Report*, July 2000, Pg. 15
[67] For the most part, it is simply referred to as Granite today.

Pro/ENGINEER database for translation to other systems, for viewing or for analysis. Few applications have been developed that use Granite One for actually creating geometry.

Granite One had one specific advantage compared to industry standard translation tools such as IGES and STEP in that it provides the third-party software with accurate feature and associativity information. When this latter capability is turned on, a change in the Pro/ENGINEER model can flow through to an external program in the same manner that PTC's own applications exhibit bi-directional associativity.

Granite One was also used as the basic geometric building block for Pro/ENGINEER 2001 released in mid-2001. It incorporated an enhanced geometry creation and editing capability called "Direct Modeling" which enabled users to double click on a model element and then edit the dimension of that element directly in the graphics window. This release also provided the ability to compare two models in order to detect differences using the ModelCHECK software the company had earlier acquired from Rand.

Users could also create a derived model from a parent model. As an example, the casting an engine block is machined from differs from the final product in that it contains excess material that will subsequently be removed and does not include features machined into the block during manufacturing. Changes to the parent model are subsequently reflected in the derived model although the reverse does not occur.

Probably the most significant enhancement in 2001 was the incorporation of advanced surface geometry capabilities directly in Pro/ENGINEER as an option called Interactive Surface Design Extension (ISDX). No longer did CDRS users have to use one program to create sophisticated geometry and then import that geometry into Pro/ENGINEER. This integration of CDRS technology took much longer than originally planned, but once done, proved to be an effective design tool.

The major problem with Pro/ENGINEER was not its technical capabilities but how it was being positioned against products such as SolidWorks and Autodesk's Inventor. Although Pro/ENGINEER-Foundation was priced competitively at $4,995, to add the newest surface geometry capability cost $3,995 for ISDX plus PTC's Advanced Surface Design Extension which cost another $4,995. For all practical purposes, a typical seat of Pro/ENGINEER still cost nearly $15,000. PTC simply was not doing an adequate job of explaining to customers and prospects why its software was worth this type of premium.

**The product strengthens but business continues to slide**

In the July 2001 issue of *Engineering Automation Report*, David Cohn[68] wrote an excellent in-depth review of PTC. Some of the issues surrounding PTC at the time included:

- While the Windchill business had increased from $13 million in fiscal 1998 to $175 million in fiscal 2000, PTC's MCAD business had decreased from $1,018 million to $754 million during the same period.

[68] David Cohn became Editor-in-Chief of *Engineering Automation Report* when Cyon Research purchased the newsletter in August 2000.

 

- The company had 250,000 seats of advanced design software installed at 30,000 customers. The top 30 accounts had more than 1,300 seats each but there were also 17,000 accounts that only had one or two seats.
- Two-thirds of PTC's revenue was now coming from service business including software maintenance as compared to less than 40 percent two years earlier.
- PTC had earlier been criticized for not spending enough on research and development. By fiscal 2000 it was spending 16 percent of gross revenues on R&D, up from just 9 percent two years earlier.
- Of the company's 4,700 employees, 2,800 were assigned to the MCAD products and 1,500 to Windchill. Likewise, of 600 sales people, 300 were devoted to MCAD, 200 to both MCAD and Windchill and 100 to just Windchill.
- PTC repackaged Windchill into more easily installable modules including Windchill ProjectLink (formerly Windchill Netmarkets) for collaborative project management and Windchill PDMLink for document management. ProjectLink was initially targeted at three specific groups of Internet-centric customers: manufacturers offering collaborative project portals, manufacturers offering private exchanges for design chain collaboration, and business-to-business public exchanges serving the manufacturing industry.

The article went on to describe PTC's extensive product line for product design, analysis, manufacturing, visualization, collaboration and data management.[69] As comprehensive as this product line was, the stock market was taking a dim view of PTC and the company's stock fell to a low of $3.97 during 2001. Things did not get any better the following year as PTC's stock fell to of $1.64 in 2002. In general, the companies revenues continued to spiral downward as shown in the following table (all numbers in millions) before finally turning up in fiscal 2005.

| Fiscal Year | MCAD Revenue | Windchill Revenue | Total revenue | Earnings (Loss) |
|---|---|---|---|---|
| 1997 | $808 | na | $808 | $219 |
| 1998 | $1,005 | $13 | $1,018 | $106 |
| 1999 | $976 | $81 | $1,058 | $119 |
| 2000 | $754 | $175 | $928 | ($15) |
| 2001 | $721 | $214 | $935[70] | ($10) |
| 2002 | $547 | $195 | $742 | ($94) |
| 2003 | $484 | $188 | $672 | ($98) |
| 2004 | $482 | $178 | $660 | $35 |
| 2005 | $503 | $218 | $721 | $84 |

During this period, PTC was being squeezed between the mid-range vendors such as SolidWorks and Autodesk and the high-end vendors such as IBM/Dassault and EDS

[69] *Engineering Automation Report*, July 2001, Pg. 5
[70] In 2003, PTC was forced to restate its revenue for prior years which resulted in reducing previously reported revenue by $33 million. This was the result of incorrectly booking service revenue.

 

Unigraphics Solutions. The most serious competition was coming from the mid-range competitors who offered software packages that were easier to learn and use than Pro/ENGINEER although the latter offered a much broader range of optional modules.

PTC spent several years working on a new version of its software that would be easier to use. The result was Pro/ENGINEER Wildfire, released in early 2003. It incorporated an entirely new user interface paradigm that utilized an object/action methodology. Once an object was selected, the user was presented with a selected list of actions that could be applied to that object. PTC priced Wildfire to match the capabilities of mid-range competitors while allowing customers to add all the task-specific applications including Windchill that they might need. Within six months, over 25 percent of the Pro/ENGINEER installed base migrated to Wildfire.

According to Evan Yares in *Engineering Automation Report*:

> "PTC will be able to walk into any customer account and go head to head with its toughest competitors without having to hem and haw about the price. My guess is that we may start seeing a resurrection of some of the swagger that used to characterize PTC salespeople in days of old (although I'm thinking that the old days of unmitigated arrogance are thankfully gone.)"[71]

Although there were some bumps in the road, Wildfire did allow PTC to get its revenue growing once again. The company also changed its marketing pitch, emphasizing what it called the Product First Roadmap. First introduced in early 2002, its basic premise was that great manufacturing companies have great products and PTC was the software vendor that could help make this happen. Unfortunately, PTC's sales people had to run harder just to stay in place as the average sales price of a Pro/ENGINEER seat dropped to under $9,000 in early 2004 as compared to nearly $20,000 in 1997. Simply stated, they had to sell twice as many copies of software just to stay even. In this adverse environment, Toyota became the company's largest customer in fiscal 2003 in terms of license and service revenue.

Although PTC continually referred to Windchill as being the key to the company's future, the fact remained that at the end of fiscal 2003 only 2,100 of the company's 35,000 customers were using Windchill software. But that did not reduce the company's enthusiasm for PLM technology. It estimated that for every seat of design software, and there were over 300,000 Pro/ENGINEER users by then, there were 10 to 30 individuals who need access to that design data. At the extreme, that meant a potential market for nine million seats of Windchill software without taking into consideration organizations using non-PTC design software.[72] Perhaps part of the problem in expanding Windchill sales was an issue facing all PLM vendors. That was the fact that companies had not done a very good job of measuring the effectiveness of past product development processes and, as a consequence, had a hard time calculating the return on PLM investments.

Significant changes took place at PTC in 2003 and 2004. In 2003 the company set out to reduce its annual operating costs by $140 million. The direct sales force headcount

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[71] *Engineering Automation Report*, March 2003, Pg. 1
[72] PTC 2003 Annual Report, Pg. 12

was reduced while the number of resellers grew rapidly to about 270 with a total of nearly 1,000 sales representatives by the end of 2004. This reseller channel was responsible for $136 million of the company's total revenue and some were beginning to sell Windchill Link as well as Pro/ENGINEER. Overall PTC employment was just over 3,000 at the end of fiscal 2004, down from nearly 5,000 at the end of fiscal 1999. By the end of fiscal 2005, it appeared that the company was on track to slowly return to $1 billion plus in revenue, a level comparable with Autodesk, UGS and Dassault.

There are several other changes at PTC that probably need to be pointed out. During fiscal 2002 through 2004 the company was spending 16 percent to 19 percent of revenue on R&D. This was more in line with what other software companies spend on R&D and compares to the six percent or so that the company was spending in the mid-1990s. Also, the company now had as many people assigned to R&D as were employed in PTC's sales and marketing organization. A decade earlier there were twice as many people in sales and marketing.

Several years later a number of customers were still using CADDS software. For example, Ukrainian-based ANTONOV Aeronautical Scientific/Technical Complex (ANTONOV ASTC) launched its newest aircraft, the AN-148 regional jet using CADDS 5i along with Windchill and Pro/MECHANICA. Likewise, Wuchang Shipyard in China was using Windchill PDMlink, Windchill ProjectLink along with CADDS 5i.

July 2005 also mark the re-emergence of PTC efforts to expand through significant acquisitions. One major deal involved paying $190 million for privately held Arbortext of Ann Arbor, Michigan. This company, which had revenues of about $40 million at the time as well as 250 employees, developed advanced software solutions for technical publishing. A number of Arbortext's customers, including Boeing and Toyoda, were also existing PTC customers.

This was followed in April 2006 by the acquisition of Mathsoft, a developer of engineering calculation software called Mathcad, for $63 million. Mathsoft had revenues of about $20 million and over 250,000 users worldwide. In typical aggressive PTC fashion, Harrison began stating in 2005 that PTC would once again become a $1 billion dollar company by fiscal 2008 with earnings in the $200 million range.

# Chapter 17

## Structural Dynamics Research Corporation

Structural Dynamics Research Corporation (SDRC) was founded in 1967 by Dr. Jason (Jack) Lemon, Albert Peter, Robert Farell, Jim Sherlock and several others. Lemon and his partners had previously held teaching and research positions in the University of Cincinnati's Mechanical Engineering Department. Initially, this was a mechanical engineering consulting company that over the years made the transition to being a full-fledged mechanical design software company. One of the company's early consulting assignments was for U. S. Steel and it was so impressed by the work SDRC did that it decided to invest in the company and for a time held about a 40 percent ownership position.

The relationship with U.S. Steel was far more than simply a financial investment. SDRC's engineers worked closely with U. S. Steel's sales and marketing people to create new markets for steel. One example was the machine tool industry which had traditionally used castings for the base of their machine tools. U.S. Steel wanted to sell these companies plate steel that could be welded into the shapes needed. SDRC's engineers developed the analytical techniques that proved to these prospective customers that the steel plate bases were an acceptable alternative. This relationship generated numerous leads for SDRC's seminars on advanced engineering design and analysis technologies. U.S. Steel also had two people on the company's board of directors during this period.

Dr. Russ Henke, who was also a University of Cincinnati graduate, joined SDRC in 1969 as director of computer operations, at a time when the company had about 20 employees. His early responsibility was to develop the company's Computer-Aided Engineering (CAE) software business and its Educational Seminar Activity. As the company developed its consulting practice, it became increasingly involved in applying computer-based analysis to the problems it encountered. There was very little engineering software available at the time and SDRC found itself developing programs needed to support its consulting work. Henke became president and chief operating officer in 1972, a position he held until he left in 1982.

One of the other early employees was Dr. Albert Klosterman who joined SDRC in 1970. For many years Klosterman was the driving force behind the company's software development activities including modal analysis software, solids modeling, surface modeling using NURBS and variational modeling as described below. Although his title changed over the years, for the most part he was SDRC's chief technical officer and managed the company's software development activities as a senior vice president. Another key employee was Jack Martz who headed the company's consulting activities for a number of years.

SDRC's primary focus was on vibration analysis. The intent of this work was to determine the natural frequencies of a vehicle or piece of equipment to determine when it would vibrate at an unacceptable level and to determine how to dampen these vibrations. Technically, this is often referred to as "modal analysis." To facilitate the work, SDRC established working relationships with both academic institutions such as the University of Cincinnati and commercial companies such as GenRad. The latter company was a key partner in that it provided the systems used to physically measure equipment and vehicle vibrations. Like most manufacturers of test equipment in the late 1960s, GenRad needed software for Modal Analysis, making the relationship mutually beneficial.

The company's early headquarters was in the town of Mariemont, Ohio, a Cincinnati suburb. The offices and laboratories were in a collection of old historic buildings. SDRC was starting to develop an educational aspect to its consulting practice and these classes were held in a classroom on the second floor of a former restaurant. The first floor was the ex-restaurant's räthskeller to which the students retired after class for beer and conversation.

In the early 1970s the company began to get more involved with the use of computers for engineering analysis, both to support its consulting work and as a means of generating revenue. Finite Element Analysis (FEA) was beginning to became an accepted engineering analysis tool about this time. FEA had evolved during the 1960s as an aerospace technology with major support from NASA. Two of the first companies to offer software in this area were Swanson Analysis Systems (ANSYS) and McNeal-Schwendler Corporation (NASTRAN) (See Chapter 22). Prior to products from these two companies being available, SDRC used FEA code it had developed internally as well as a public domain version of NASTRAN available from NASA referred to as COSMIC NASTRAN.

Lemon felt strongly that timesharing systems were the wave of the future and that SDRC should focus on providing software on these systems rather than license its software for a one-time fee. Initially, the company sold ANSYS and NASTRAN on a timesharing basis using computers operated by U. S. Steel. This was followed by resale agreements with Control Data's Cybernet timesharing operation and Tymshare, a west coast company that offered timesharing services on Scientific Data Systems 940 computers and Digital PDP-10s. Around the same time, SDRC productized its own FEA software, Superb, and began offering a modeling package called Supertab.

Early FEA programs analyzed models that had a few hundred to a few thousand individual elements. Input data was prepared by laying out a grid of elements on a drawing of the part and then carefully measuring the coordinates of each node. These values were entered on to coding forms which were then manually keypunched into 80-column punch cards. It was a laborious process and one very susceptible to errors.

SUPERTAB was one of the first programs that automated the process. It became available to SDRC analysts and clients around 1975. The initial version of the software simply enabled a user to digitize the two ends of a line and would then evenly space intermediate nodes along the line. The nodes could then be connected to form individual elements. While the primary objective was to provide a means for creating input to the company's own Superb program, SDRC soon added the capability to generate both ANSYS and NASTRAN input. SUPERTAB used Tektronix storage tube terminals as its primary input device. Initially it ran on the various timesharing services the company used.

In 1978, SDRC moved into a new 75,000 square foot office facility in Milford Ohio, about six miles from the Mariemont location. In addition to typical office space for its engineering and software staff, it included a large laboratory area where equipment supplied by clients could be tested. One of the major areas of consulting activity continued to be noise and vibration tests for automobile manufacturers. The teaching experience of Lemon and many of his associates was reflected in a large lecture hall and other training facilities incorporated into the new office complex.[1] A important aspect of the company's business consisted of classes for clients in how to use FEA and other emerging technologies as design tools.

While the training classes in Milford and at its other offices generated a moderate amount of revenue for SDRC, they were far more important in that the classes created a growing demand for the company's consulting and software services. The entire notion of FEA or mechanical simulation as some referred to it, was a foreign concept to most engineers at the time. Few of them had come across these tools during their college years or in their earlier engineering practice. Literally thousands of engineers received their first exposure to this new technology via SDRC's training programs.

**SDRC enters software market**

By the mid-1970s there was pressure within SDRC to begin selling the company's software on a packaged basis as well as on timesharing systems. Lemon in particular was reluctant to do so in that he believed that there was more money to be made by charging for the software on a usage basis. While some companies had expense budgets for this type of work, other companies preferred to make a capital investment in hardware and software. Around 1977, the company began selling a licensed version of SUPERTAB for use on customer owned computer systems such as Digital PDP-11s.[2]

By 1978, in addition to its Milford, Ohio headquarters, SDRC had offices in Detroit, Chicago, Boston, and San Diego as well as in England and France. In addition to its mechanical testing and education services, SDRC by this time was beginning to sell its software products more aggressively. The software was provided in three different ways; customers could license the software for use on their own computers, they could access it via time-sharing over telephone lines or they could bring their data to SDRC and have the analysis work done either by themselves or SDRC engineers on SDRC equipment. Applications supported by the company included static and dynamic FEA, elastic-plastic stress and deformation analysis, heat transfer and fluid flow studies. SDRC used a combination of its own software and software licensed from other developers to support this work. The predominate analysis software being used at the time was NASTRAN and ANSYS.

The most significant internally developed software package continued to be Supertab. By 1978 Version 2.0 was being used by the company and its customers. Primary competition for the timesharing version of SUPERTAB came from McDonnell Douglas Automation Company (MCAUTO) which offered a modeling package called Fastdraw. MCAUTO, which eventually became the parent company of Unigraphics, was probably the country's largest vendor of technical timesharing services with a library of dozens of engineering design and analysis programs. (See Chapter 19). In March 1977

[1] SDRC maintained the informal atmosphere of Mariemont at its new facility in Milford. Outside the cafeteria used by the students, the company installed a bar with a beer tap that initially was available to employees and students at all times. Eventually, the company's management realized that some of its employees were engaged in potentially dangerous testing activities and reduced the time the bar was open to after working hours. Friday afternoon "beer blasts" were not unique to Silicon Valley.

[2] Interview with Richard Miller, March 9, 2004

CDC introduced UNISTRUC (Unified Structural Design System) for use on the company's Cybernet timesharing system.

As far as software that could be run on internal systems, there were two competitors. Around this time, PDA Engineering began offering PATRAN, a modeling and postprocessor. In the fall of 1977, Tektronix introduced its FEM181 system that ran on the company's 4081 stand-alone graphics system. None of the traditional turnkey CAD vendors were supporting FEM or FEA software to any significant extent nor did they provide translators that could automatically transfer design data to analysis programs. The packaged version of SUPERTAB sold for $10,000 or $20,000 if the customer wanted a copy of the program's source code. A typical hardware configuration cost from $70,000 to $130,000. A timesharing user needed to spend $12,000 to $20,000 for a graphics terminal as well as incur hourly timesharing charges that typically ran from $50 to $300 per hour. Once a company began using a timesharing system for FEM more than 500 hours per year, the capital expenditure to install the software internally started to become increasingly attractive.

At this point the company was growing fairly rapidly. By mid-1977 employment was up to about 220 people, of which more than 85 percent worked in Milford. With rapidly growing sales, the company was becoming quite profitable as shown in the following table:

SDRC Revenue and Profits[3]
(Amounts in Millions)

| Fiscal year Ending in March | Consulting Service | Networks and Software | Education | Total Revenue | Profits after Taxes |
|---|---|---|---|---|---|
| | | | | | |
| 1974 | $2.4 | $0.6 | $0.2 | $3.2 | $0.1 |
| 1975 | $2.9 | $0.8 | $0.2 | $3.8 | $0.0 |
| 1976 | $3.7 | $1.0 | $0.2 | $4.9 | $0.3 |
| 1977 | $4.9 | $1.3 | $0.3 | $6.5 | $0.5 |

Although the company's total revenues were low compared to CAD system vendors such as Applicon and Computervision, SDRC's customer base read like a who's who of the automotive and heavy equipment industries: Allis Chalmers, Borg Warner, Carrier, J.I. Case, Chrysler, Clark Equipment, John Deere, Eaton, FMC, Ford, General Electric, General Motors, etc.

**Developing a working relationship with Tektronix**

One of the most difficult business issues facing SDRC was how to develop a sales and distribution channel, both internally and with business partners. This was particularly difficult for an organization whose management was made up of academically-oriented engineers. The initial sales organization was set up as SDRC Systems under Sid Barton. This is the group that eventually evolved into the CAE International organization

[3] Authors personal papers

 

described below. The company was eager to establish marketing relationships with other companies that could help it sell SDRC software packages.

In the late 1970s, Tektronix (see Chapter 22) dominated the computer graphics market as much as Microsoft dominates the PC operating system market 25 years later. Its 4014 storage tube terminal was used extensively with both timesharing and stand-alone systems for engineering design and analysis. The 4014 was packaged with an Interdata minicomputer and sold as the 4081. This, in turn, was used as the platform for a finite element modeling system, the FEM181. It was slow to gain market momentum but Tektronix was committed to expanding its presence in the mechanical engineering market. In August 1978, Tektronix established a new organization, the Mechanical Engineering Graphics Business Unit (usually referred to simply as MEG) under the management of Claude Tucker.[4]

To jump start its activities in the mechanical systems market Tektronix took two steps. It licensed AD-2000 from Manufacturing and Consulting Services (see Chapter 15) and it signed an agreement with SDRC to resell that company's SUPERTAB software. Tektronix had taken its 4014 terminal and repackaged it in a more user friendly console called the MEG121. It then added a Digital PDP-11/34 minicomputer to the MEG121 and called this stand-alone version that was capable of running SUPERTAB the MEG131. Tektronix wanted a resale agreement with SDRC since it realized that the 4081-based FEM181 system was not appealing to many prospects since its Interdata computer had little third-party engineering software available.

In general the FEM181 software and SUPERTAB were roughly comparable. SUPERTAB had somewhat better geometry features while FEM181 might have been easier to use. In particular, FEM181 had an excellent "shrink" feature that facilitated the detection of model errors and it also had an excellent mesh generator option. The two software packages sold for about the same amount.

Tektronix subsequently began selling SUPERTAB running on the MEG131 as well as copies of SUPERTAB to run on customer provided Digital minicomputers. The first MEG131 with SUPERTAB was sold to Whirlpool Corporation in December 1978. About the same time, Tucker was replaced as head of the Tektronix MEG business unit by Jon Reed who decided to focus on the AD-2000 portion of the company's product line.

A new agreement was worked out with SDRC in early 1979 under which SDRC took on the responsibility for sales and support of both the FEM181 and SUPERTAB software while Tektronix sold the graphics hardware and in some cases MEG131 computer systems. This relationship lasted until late 1979 when Tektronix suddenly decided to get out of the mechanical software business, leaving SDRC to proceed on its own.

### Getting in bed with General Electric

In addition to Tektronix, SDRC also had a co-operative development and marketing agreement with Applicon under which the two companies worked to integrate Applicon's design software with SDRC's finite element modeling and analysis software.

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[4] I was working for Tektronix at the time as the district sales manager in Denver, Colorado and was promoted to national MEG program coordinator when MEG was established. In this role I was involved in most of Tektronix's relationship with SDRC for the next 18 months.

 

In mid-1980, General Electric, which owned 22 percent of Applicon, made an offer to acquire the remainder of the company just before that Applicon went public, an offer that was rejected. Later that year, GE acquired Calma from United Telecommunications for $170 million. Throughout this period, numerous GE operations were SDRC clients either for the company's consulting services or its software.

As part of the agreement between Applicon and SDRC, Applicon was reselling SUPERTAB while SDRC had set up half a dozen automated design service centers using Applicon CAD systems. (See Chapter 7). One reason for the close working relationship between the two companies was that they both used Digital computer systems making it easy for customers to install their software and exchange data between packages. By early 1982 the relationship between the two companies deteriorated and a number of SDRC people including Dick Miller, Rex Smith and Paul Vollbracht left to join Applicon. They were followed a few months later by Russ Henke.

Meanwhile SDRC had established a subsidiary, CAE International, in 1977 as the company's sales and support arm. Lemon and Farrell believed that establishing separate corporate entities with their own stock would provide senior managers with financial incentive to run their own businesses. In addition to CAE International, two other divisions of the company were established; SDRC Systems and SDRC (the consulting part of the business). The people assigned to CAE International and SDRC Systems were still SDRC employees and worked in the same facility.

There were two reasons for SDRC joining forces with GE. On one hand, Lemon was a strong believer in the future of timesharing even though its impact on technical computing was starting to slip with the growth of minicomputers and GE was a major factor in that industry through General Electric Information Services Company (GEISCO). The second reason in Lemon's mind was that GE had hundreds of sales people who could be turned loose to sell SDRC software. Unfortunately, most of these people knew little about the engineering software market. According to Dick Miller, "Floyd Soulé (a salesman in Detroit) could outsell the whole GE sales force."[5]

As part of CAE International, SDRC began reselling NC software that had been developed under the direction of Joe Frazier. In July 1981, Frazier was named president of this subsidiary. Then in November 1981, GE announced a joint venture with SDRC under which the two companies planned to open five "productivity" centers equipped with Calma CAD/CAM systems, GE robotics equipment and GE NC controllers. Combined with SDRC's analysis software, these centers would enable clients to take projects from conceptual design through prototype manufacturing. The work could be done either by the clients' own personnel or SDRC would do it on a consulting basis.

The productivity centers fit in with GE's concept of the "factory of the future." (See Chapter 11). In December 1981 the two companies announced that GE had acquired a 49 percent interest in CAE International and it subsequently became known as GE-CAE International. Basically, GE-CAE International was a sales operation. The development of SDRC's software and actually ownership of the technology remained with SDRC itself.

The GE involvement in SDRC did not sit well with many of the company's employees. The company had been consistently profitable during the 1970s and the expectation among its people had been that the company would go public around this

[5] Interview with Richard Miller, March 9, 2004

time. When it did not, stock options employees had counted on suddenly became of questionable value. It would be several more years before the company finally went public and employees could cash out their options. In addition, GE's style of management just did not sit well with this bunch of engineers. Henke, for example, thought that the U.S. Steel relationship was a better deal for the company.[6]

In early 1984 Brad Morley became manager of product marketing at GE-CAE International while Gerald Knobeloch was made manager of North American operations, James Sherlock was manager of international operations and Martin Meads was manager of European operations. In May 1985 Knobeloch became general manager of this organization.

**The transition from CAE to CAD**

Chapter 11 describes how Calma, now owned by GE, resold SDRC software packages as components of its broad CAD/CAM product line. For the sake of brevity, that material is not repeated in this chapter. The fact that GE owned Calma outright and held a 49 percent interest in GE-CAE International undoubtedly influenced SDRC's efforts to broaden its product line. For the most part, SDRC concentrated in areas such as solids modeling as well as its legacy analysis software and consulting rather than competing directly with Calma. Some of the people at SDRC had a rather casual attitude concerning Calma, considering that company to simply be a distributor of GEOMOD.[7]

Starting in 1980, SDRC's overall product nomenclature for the company's integrated design and analysis software was called I-DEAS which stood for <u>I</u>ntegrated <u>D</u>esign <u>E</u>ngineering <u>A</u>nalysis <u>S</u>oftware (the – was due to the fact that another company was already using the IDEAS name). This software suite covered conceptual design using both wireframe and solids modeling, drafting, finite element modeling pre- and post-processing and a variety of analysis modules as well NC part programming.

Not all these capabilities were included when I-DEAS was launched in the early 1980s but were added as time passed. The intent was to use a common database and a consistent user interface. The company also began development of a faceted solids modeler around this time which eventually evolved into GEOMOD described below.

It took some time for SDRC to be recognized as a viable CAD software vendor, probably because the company was not particularly interested in the drafting portion of the design cycle and other vendors such as Computervision and Applicon were heavily engaged in that task. Daratech's *1983 Survey and Buyers' Guide* covered 91 CAD/CAM software vendors without mentioning SDRC. From 1983 through 1985, I managed competitive analysis for Auto-trol Technology. Part of my responsibilities included maintaining a competitive notebook for the company's sales force. Here also, SDRC was conspicuous by its absence. It would take several more years before the company would be considered more than a vendor of mechanical engineering analysis software and consulting services.

**SDRC adds solids modeling**

GEOMOD, which was introduced in 1983 (beta test versions had been installed at GE the prior year), added a NURBS (Non-Uniform Rational B-Spline) boundary

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[6] Interview with Russ Henke, March 22, 2004
[7] Personal notes from NCGA-84 Conference

 

representation capability to the earlier faceted modeler. Curved surfaces were represented using planar faceted surfaces with user control over the size of these facets. This improved software performance but at the cost of some lost precision. The software synchronized these two representation of geometry. In addition, the user could record a design session in a manner that created the equivalent of a Constructive Solid Geometry (CSG) data representation.[8]

There were three basic means of creating geometry in GEOMOD:

- Boolean operations such as join and subtract using primitives including blocks, cones, spheres, tubes cylinders and hexahedrons.
- Extrude and revolve two-dimensional boundaries defined by lines, arcs and B-spline segments. These boundaries could be swept along a spline.
- Skinned surfaces could be lofted across a series of arbitrary two-dimension sections. This surface could then be used to define a solid object.

Mass properties of models created using these techniques could be calculated directly by the GEOMOD software.

Not only could individual parts be modeled with GEOMOD, but assemblies of parts could also be defined. The software's user interface depended somewhat upon which computer and terminal configuration was being used. SDRC supported Digital VAX computers with a wide variety of storage tube and raster refresh terminals, IBM mainframes and Apollo workstations. Typically, commands were entered either using the terminal or workstation's keyboard or selecting screen menu items using a tablet and cursor. The initial version of GEOMOD was written almost entirely in FORTRAN.

A key aspect of GEOMOD was its ability to interface with other I-DEAS modules. Kinematic analysis was performed with a Mechanism Design module while SUPERTAB was used to prepare model data for finite element analysis using either SDRC software such as SUPERB, FRAME, SYSTAN, FATIGUE and MODAL-PLUS or third party packages including ANSYS and NASTRAN. By this point in time SUPERTAB had been complemented by an automatic mesh generation program called TRIQMESH.

Drawing production was handled by exporting GEOMOD data to GEODRAW, a package the company licensed from Computer Aided Systems for Engineering (CASE) or other third-party drafting programs. Data was transferred either as a wireframe model or as view-dependent surface boundary descriptions with hidden lines removed. In the 1985 timeframe, changes to the GEOMOD model did not result in changes being made directly to the GEODRAW drawings nor did changes to the drawings affect the model. That technology would come later. GEODRAW could be used to define two-dimensional profiles that could then be imported into GEOMOD and used for extrusions and revolves.

By early 1985, SDRC had installed nearly 300 copies of GEOMOD at over 100 customer locations. GE-CAE International typically sold I-DEAS software on a per-installation basis. As of October 1985 basic GEOMOD sold for $35,000, the system assembly option for $20,000, Mechanism Design for $5,000 and GEODRAW for $25,000. Workstations versions of the software were priced lower plus the company offered substantial quantity discounts. In addition to buying I-DEAS software from GE-

[8] *The Anderson Report*, September 1985, Pg. 4

CAE International, customers could purchase complete turkey systems from Calma, IBM and GenRad. The latter, of course, was focused primarily on vibration testing systems.

About 65 percent of the company software revenue came from the GE-CAE International sales force while the balance came from its turnkey partners.
Robert Johnson, the industry's leading analyst of solids modeling solutions at the time was duly impressed by the software's modeling capabilities, especially GEMOD's ability to distort objects by bending and twisting and its ability to interface to analysis programs. He was concerned, on the other hand, that all curved surfaces were approximated with planar facets.[9] A major drawback of GEOMOD in this timeframe was that the interface with Calma's DDM software and SDRC's own GEODRAW was via an IGES translator.

SDRC's sales force emphasized a consultative sales approach where the objective was to understand the prospects engineering process and then try to match SDRC's software products to that process. The company was very amenable to trial installations of its software as long as the prospect paid for and attended a training course. Over 90 percent of such trial accounts ended up purchasing the software. As of the fall of 1985, over 50 percent of the company's software installations were on Digital VAX computers, another 25 percent were on Digital PDP-11 computers while the balance was split between IBM mainframes and Apollo workstations.[10] The defense, aerospace and automotive industries made up slightly less than 50 percent of the company's software business.

The September 1985 issue of *The Anderson Report* contained summaries of interviews with three SDRC users. Hughes Electro Optical and Data Systems Group had 48 workstations operating on Digital VAX 11/785 and Apollo computers running I-DEAS software. About 75 percent of this usage was with GEOMOD. According to Bill Marks, a senior staff engineer with Hughes, the company was using MODAL-PLUS to compare computer simulation data to physical test data. One of his more interesting comments was that Hughes was going through design iterations without relying on paper drawings. They were, however, using GEODRAW for other applications and Marks referred to it as "a diamond in the rough." Overall this division of Hughes was very pleased with SDRC software and planned to add 300 to 400 workstations over the next two years, mostly using Digital MicroVAX computers. Marks was particular high on SDRC as a vendor, "SDRC engineers understand my problems and are almost like consultants compared to the used car salesman approach of some companies." The other organizations interviewed, NASA, Langley and Honeywell, Commercial Avionics Division, were comparably enthusiastic about I-DEAS and GEOMOD.[11]

Overall, by the end of 1985 SDRC was well respected by the engineering design community, not only as a vendor of CAE technology but increasingly as a vendor of a broader range of design solutions.

### Continuing the transition to becoming a CAD vendor

Over the next several years, SDRC continued its transition away from being considered a mechanical engineering consulting firm to being more of a traditional

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[9] Johnson, Robert H., *Solid Modeling: A State-Of-The-Art Report, Second Edition,* October 1985 Management Roundtable
[10] *The Anderson Report*, September 1985, Pg. 4
[11] *The Anderson Report*, September 1985, Pg. 4

 

software organization. It should be noted that throughout this transition, there did not appear to be any intent on the part of the company to turn itself into a turnkey systems vendor. Since GE owned 49 percent of GE-CAE International and all of Calma, it is fairly clear that Calma was the designated systems house while SDRC was encouraged to focus on the software and consulting aspects of the market.

In April 1986, SDRC introduced I-DEAS software that could be used to optimize part designs by minimizing the mass of these parts. This was several years before Rasna began offering comparable software. The SDRC software enabled users to work with multiple load cases in order to ensure the integrity of the design.

SDRC, which had primarily been supporting Digital, IBM and Apollo computer hardware, ported the I-DEAS suite of programs to Hewlett-Packard's HP-9000 Model 320 workstations in early 1986. The arrangement between the two companies had SDRC assisting in pre-sales activities, HP actually selling the hardware and software and SDRC providing post-sales software support. Software prices started at $18,000 per seat.

GEODRAW was enhanced in May 1987 with an icon-based user interface, more dimensioning capabilities, intelligent line fonts and a macro language. The price was reduced to $6,500 with quantity discounts available. SDRC also implemented a floating license that resulted in customers paying for the maximum number of simultaneous users rather than the number of workstations on which the software could run. In other words, if a customer had 20 workstations but only 10 would be running GEODRAW at any one time, then it only had to pay for 10 licenses. In addition to Digital and Apollo workstations, the software was also available for Sun systems but apparently not HP workstations.[12]

In a rather interesting development that September, SDRC announced an enhanced interface between I-DEAS and Computervision's CADDS 4X software. A GEOMOD design could be transferred to CADDS 4X for drafting and NC tape preparation. Conversely, a CADDS 4X design could be transferred to I-DEAS for structural and thermal analysis. The transfer mechanism was an enhanced or "flavored" version of IGES. At this point in time, I-DEAS was available on Sun workstations so the SDRC software could run in a network with Computervision's Sun-based CADDStations.[13]

**SDRC finally goes public**

Ron Friedsam, a 17-year veteran of Burroughs, was hired as CEO in 1986. Prior to his being hired, the company had been lumbering along earning just $1.5 million on annual sales of $39 million. Friedsam injected SDRC with a "big-company" management and discipline style it had not previously known. After his arrival, the company's revenues and earnings picked up sharply. While Friedsam energized the company, his people management skills could have been better as evidenced by the legal problems the company ran into a few years later.

This led, in August 1987, to the filing of a preliminary stock prospectus with the Securities and Exchange Commission to sell three million shares of stock at $14 to $17 per share. The plan was for the company to sell half these shares to raise operating capital

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[12] *The Anderson Report*, May 1987, Pg. 7
[13] *The Anderson Report*, September 1987, Pg. 7

 

and for several stockholders to sell the other half. As part of the arrangement for going public, General Electric sold its interest in the company to a group of outside investors.

It is interesting to note that *CAD/CIM Alert*, in describing the pending offering, described SDRC as a traditional CAD/CAM company rather than as a MCAE company as it was typically being portrayed. The offering was unwritten by Morgan Stanley & Company of New York and Robertson, Coleman & Stephens of San Francisco.[14] The company closed on this offering later that year at $12.50 per share, somewhat less than what was originally expected. A month after SDRC's public offering, the stock market crashed in October 1987.

**Life as a public company**

One aspect of SDRC's software distribution strategy that has not been previously mentioned was the company's relationship with IBM. SDRC arranged to have IBM sell a version of I-DEAS implemented to run on IBM computer systems. Called CAEDS for <u>C</u>omputer <u>A</u>ided <u>E</u>ngineering <u>D</u>esign <u>S</u>ystem, it initially ran on IBM mainframes using that company's 5080 graphic display terminals. At the same time, IBM was marketing Lockheed's CADAM software which was predominately drafting oriented (See Chapter 13) as well as CATIA. In late 1987 SDRC ported I-DEAS to IBM's RT/PC workstation running the AIX version of UNIX. This latter version included a new FEA package, Integrated Finite Element Solver, which handled linear static, dynamic and potential flow problems and sold for $7,200. A new drafting module, CAEDS Dimensioning, sold for $9,800.

In 1987 SDRC had total revenues of $61.2 million of which 60 percent represented software sales and services while the other 40 percent represented the company's traditional consulting business. Net earnings were $3.6 million. About 40 percent of the software business was international. SDRC was basically organized into two divisions, CAE International and Engineering Services. If a prospect was particularly analysis oriented, SDRC typically had a good shot at the business. If the application was more production design and drafting or manufacturing oriented. SDRC sales personnel had an uphill fight.

At this point in time the company's software was being licensed on Digital, Apollo, IBM, HP and Sun Microsystems workstations, minicomputers and mainframes. SDRC probably was supporting more different platforms than any other CAD/CAM vendor and had over 5,500 software licenses installed at 1,900 customer sites. IBM was the company's largest reseller of software products handling about 15 percent of SDRC's total software sales in spite of the fact that it was also marketing CADAM and CATIA.

Release 4.0 of I-DEAS was announced in April 1988. SDRC was continuing to put substantial resources into the development of GEOMOD which was fast becoming the company's flagship product. The company referred to GEOMOD as I-DEAS Solid Modeling and GEODRAW as I-DEAS Drafting. As mentioned earlier, GEOMOD combined a faceted modeler for speed with a boundary representation (B-Rep) modeling capability for precision.

Release 4.0 greatly enhanced the user's ability to select and modify individual geometric elements in the model. After all the desired changes were made, the model could be converted into a B-Rep data file in a single operation. One negative aspect of

[14] *CAD/CIM Alert*, August 1987, pg. 3

 

this method was that I-DEAS models tended to be larger than those of competitors and took longer to open. SDRC recognized that performance was an issue and Release 4.0 speeded up many operations on Digital and Apollo hardware by 40 percent and by 100 per cent on IBM systems due to some special performance enhancement work by the company's programmers. This release also implemented the ability to update drawings based upon changes made to solid models but changes to drawings did not automatically change the solid model.

Supertab was now known as I-DEAS Engineering Analysis. Release 4.0 added an adaptive meshing capability to the software. This version of I-DEAS created a finite element model at an arbitrary mesh density and then analyzed the model. Based upon the results, the software automatically re-meshed the model with finer meshes in high stress areas and repeated the analysis step until the designer was satisfied with the results.

In a May 1988 article, *The Anderson Report* was optimistic about the companies future.

> "Two trends enhance SDRC's opportunity for continued growth. First is the incredible price/performance gains in technical computing. MCAE applications need lots of MIPS and MFLOPS which continue to decrease in price. Second is the evolution of success stories from companies that are currently using MCAE to improve their competitive edge. These 'early adaptors' have set an example of how MCAE technology can be successful, thus building the confidence level for a broad range of companies to utilize these tools. We continue to be very optimistic about the future of SDRC."[15]

In spite of this optimism for SDRC, *The Anderson Report* did not mention the company again for nearly two years.

**SDRC's business and product offerings mature**

By 1990 Parametric Technology was beginning to have a significant impact on the mechanical CAD market with the parametric design capabilities of its Pro/ENGINEER software. SDRC countered in early 1990 with I-DEAS Release V which incorporated the company's first implementation of an alternative design technology called variational geometry. While parametric design uses a sequential equation solver for predefined geometry, a variational system uses a simultaneous equation solver and accepts less structured input. The proponents of variational geometry technology believed that it was more flexible than parametric design and enabled users to make changes more easily.[16] The debate between the two techniques would go on for the next decade.

I-DEAS' initial implementation of variational design was basically limited to two-dimensional geometry. It would be several more years before it would be a full-fledged three-dimensional design capability. The 1990 version of I-DEAS also included feature-based modeling with the ability for the user to add custom features to the standard library of holes, ribs and bosses. Dimensions could now be displayed on solid models. SDRC began to see some national attention with a two-page article in the June 25, 1990 issue of

[15] *The Anderson Report*, May 1988, Pg. 3
[16] *The Anderson Report*, February 1990, Pg. 1

*Forbes Magazine.* Unfortunately, the *Forbes* article gave the impression that SDRC was the only significant company in the mechanical CAD industry.[17]

*The Anderson Report* had a follow-up profile on SDRC in its August 1990 issue. Brad Morley was now the senior vice president of the company's software division. SDRC's revenues were growing nicely from $75 million in 1988 to $94 million in 1989 and an expected $116 to $120 million in 1990. The user base had exploded to 23,600 licenses at 4,300 customer sites. The company's president was quoted in the *Forbes* article as saying "More and more, people are buying our I-DEAS software to be used all the way from initial design to manufacturing, a full soup-to-nuts offering, rather than just installing our solids modeling or analysis products as a front end to traditional CAD systems."[18] While the company had no overt intention to get out of the consulting business, the fact was that software now constituted 75 percent of SDRC's overall revenues.

As the I-DEAS software continued to evolve, the integration between design and analysis was strengthened with each release. The company also put substantial effort in to improving the software's user interface, adopting standards such as the X.11 graphics specification. It also broadened the types of analysis that could be handled incorporating plastic mold filling and cooling simulation.

Once again the nomenclature was changed. The main modules were now called I-DEAS Part Design (solids modeling), I-DEAS Assembly Design (included interference detection), I-DEAS Mechanism Design (complex motion simulation), I-DEAS Drawing Layout (organize drawing views and prepare preliminary drawings), I-DEAS Drafting (formerly GEODRAW), I-DEAS Finite Element Modeling (mesh generation and interfaces to third party analysis software), I-DEAS Model Solution (SDRC's own analysis software) and I-DEAS Optimization (knowledge-based tool for design refinement). The NC software was the Graphic Numerical Control package developed by England's CADCenter and adapted to work with I-DEAS. SDRC's implementation was called I-DEAS GNC.

In the early 1980s SDRC acquired database technology that had been developed internally at General Motors and initiated the development of its Data Management and Control System (DMCS). This work was funded by General Electric. The software was structured so that it could be customized for widely different applications. DMCS was tested by multiple divisions of GE and by the U.S. Air Force for a number of years. By early 1991, there were over 40 installations of this software and SDRC began aggressively expanding its software product mix to encompass a broad range of data management functions. DMCS handled functions such as managing metadata (data about data) as well as inheritance and ownership issues.

Although developed to work with I-DEAS, SDRC was adamant that DMCS was insensitive to which design system was being used. It was built on top of the Oracle relational database management system although the company was considering enhancing its capabilities by replacing Oracle with an object-oriented database system within the next two years.[19] As far as I can tell, this never happened. DMCS would eventually morph into Metaphase as described below.

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[17] Wiegner, Kathleen K., *Forbes Magazine*, June 25, 1990, Pg. 131
[18] *The Anderson Report*, August 1990, Pg. 5
[19] *CAD/CIM Alert*, March 1991, Pg. 1

 

In addition to DMCS, SDRC also offered I-DEAS Data Manager (IDM) which provided data management capabilities to small groups of I-DEAS users. IDM was intended to primarily be used by I-DEAS users and worked with the same MOTIF user interface as did I-DEAS. It particularly helped designers manage product data as it moved through various stages of the design and manufacturing process. Prior to the release of IDM, SDRC users were limited to maintaining model and drawing files using the basic file management capabilities provided by the operating system of the computer they were using. DMCS was fairly expensive software. Its base price was $45,000 for the first five users. Additional users cost $1,500 to $4,500 depending upon the functions implemented and the number of users. IDM cost $1,500 per user.

SDRC changed the way it designated new I-DEAS software releases in early 1991. Its latest version was now called I-DEAS Level VI. It incorporated expanded variational design capabilities to include equations in the relationship definitions. Level VI also included new sheet metal and tolerance analysis modules. Perhaps the most significant enhancement was the addition of a graphical tool called the Dynamic Navigator to the I-DEAS Drafting software. When the user pointed a cursor at a graphical element, the software highlighted end points, mid points, intersections and tangencies to existing geometry. This was very similar to a technique implemented by Ashlar in its Vellum product and would eventually lead to a lawsuit against SDRC by Ashlar. I-DEAS' user interface was also enhanced to include menus that displayed just the commonly used commands, much like Windows does today.

As mentioned elsewhere in this chapter, SDRC's product suite was not particularly strong in regards to drafting software. I-DEAS Drafting was a third party product that accepted data from I-DEAS' design software in IGES format. This meant that other products could be used equally well for drafting, including AutoCAD. SDRC and Autodesk established a joint marketing relationship under which the concept of using AutoCAD to document I-DEAS designs was promoted. The two companies jointly developed an interface package called I-DEAS SOLID Link.

About this point in time, SDRC hired Bob Fischer as a senior vice president. He had been running the Computervision Division of Prime Computer until November 1990. SDRC closed out 1991 with announced revenues of over $146 million prior to a later restatement described below. Consulting services now represented just 20 percent of the total, but an important 20 percent.

The company's stock was being heavily pushed by the investment community in the fall of 1991. With its stock selling for $21 to $23 per share, Prudential Securities, Morgan Stanley and Robertson, Stephens & Company all had buy recommendations. Apparently based upon company guidance, they all saw SDRC generating over $180 million in revenue in 1992. It didn't happen – the company initially reported revenues of $163 million which were later restated to $149 million. By late 1992, the company's stock would be selling for just over $10.

**Shifting into high gear**

When I launched *Engineering Automation Report* in March 1992, the feature article in the inaugural issue was on SDRC. I summed up the company's position as follows:

 

> "SDRC has a strong product line that is built around their own solids modeling technology. They approach the needs of the user with a focus on design and analysis. This differs from most traditional CAD/CAM vendors who have approached it from a design, production drawing and manufacturing point of view. As these vendors moved more towards supporting analysis needs, SDRC extended its product line into the drafting and manufacturing realm."[20]

The article discussed a number of strengths SDRC brought to the table, especially the ability to tightly link its analysis software with I-DEAS' solids modeling capability. In addition, the fact that SDRC continued to perform mechanical engineering consulting assignments was seen as providing a degree of practicality to the company's software development efforts that competitors lacked. Another positive was the broad range of platforms the company supported including Digital, IBM, HP, Sun and SGI machines.

On the other hand, feedback from users indicated that I-DEAS solids modeling software created excessively large data files (this was at a time when memory was still fairly expensive and high-end workstations typically had 64MB or less of main memory) and slower performance, particularly for loading models, compared to competitive packages such as Pro/ENGINEER. The fact that both the NC and detailed drafting software came from third parties and had limited interoperability with I-DEAS solids modeling was also seen as a detriment. In fact, a number of SDRC customers used other packages for meeting their drafting and manufacturing needs.

After nearly six years of increased earnings, SDRC stumbled in the third quarter of 1992. On September 8$^{th}$ the company announced that earnings for the quarter would be $0.10 to $0.14 per share, significantly less than the $0.17 analysts had expected. Wall Street was brutal, knocking its stock price down $4.67 in one day to $10.50 even though revenues were still expected to be up 10 to 15 percent. This compared to a 12-month high of $30.

When the results were finally posted, revenue was up just two percent, mostly as a result of slower international sales. When the year was over, sales were up 12 percent to $163 million while earnings decreased 19 percent to $14.5 million except these numbers would eventually be restated downward dramatically. Rapidly growing PTC was obviously starting to have an impact on the company. This was the beginning of a period of strained relationships between SDRC and the investment community.

Probably the most significant product-related announcement in 1992 was the establishment of a joint venture with Control Data Systems, Inc. known as Metaphase Technology, Inc. Metaphase planned to develop a new generation of Product Data Management software using SDRC's DMCS and CDSI's EDL (Engineering Data Library) products as the starting point. At the time this new organization was established there were about 2,000 licenses of DMCS in use at 100 customers while there were 5,000 licenses of EDL in use at 500 sites.

The intent was that both SDRC and CDSI would sell the PDM solutions created by Metaphase. In addition, the new company planned to look for other distribution channels including companies that would incorporate Metaphase solutions into their product lines. Robert Nierman was appointed president of Metaphase Technology and

[20] *Engineering Automation Report*, March 1992, Pg. 6

Jim Hepplemann, who had been with CDSI, was the new joint venture's chief technology officer. For the next four years they led the development of the Metaphase product line which basically used a client/server architecture. As 1992 transitioned in 1993, customers were starting to wonder when I-DEAS Level VII would finally show up.

**A new generation of software**

In March 1993 SDRC introduced a major overhaul of the company's software product line. Called I-DEAS Master Series rather than simply I-DEAS Level VII, the software implemented new modeling capabilities, a new user interface, the concept of a "master model" and a team approach to large projects. The heart of the system was the I-DEAS Master Modeler which combined wireframe, surface and solids modeling within a single database. It incorporated feature-based dimension-driven design techniques along with a fully-integrated variational geometry constraint system. A particularly attractive feature was the ability to define where two surfaces were tangent to each other and to maintain this relationship as surface geometry was changed. *EAReport* described it as the "equivalent of electronic modeling clay."[21]

The new software extended the previously introduced two-dimensional Dynamic Navigator to handle three-dimension data. The I-DEAS Master Series user interface was predominately icon oriented. Command palettes dynamically reconfigured themselves based upon the context of the current work being performed. SDRC claimed that this reduced the number of keystrokes required to accomplish most tasks by 70 percent. I-DEAS Master Series also introduced Team Data Manager, a department-level model and drawing management system that facilitated project-level concurrent engineering. Enterprise-wide data management was handled by DMCS (the new Metaphase software was still off in the future).

Other developments included SDRC's own NC software to complement the GNC package the company had been marketing. Called I-DEAS Generative Machining, it worked off of the I-DEAS master model. When the model was modified, tool paths were supposed to be updated to reflect these changes. In addition, I-DEAS Drafting was now bi-directionally associative with the model database. Analysis software was enhanced to incorporate a Simulation Advisor that helped step users through the finite element modeling and analysis process.

Overall, the software incorporated numerous capabilities that were on the front edge of CAD/CAM/CAE technology. There were some rough edges but overall this was a significant step forward for SDRC and was expected to enhance the company's ability to compete with PTC. It also clearly showed that SDRC planned to be considered a broad range software supplier and not simply a vendor of design and analysis software.

SDRC began shipping I-DEAS Master Series in late June 1993 but soon ran into some problems. Prospects were having problems completing benchmarks with the new software and it took some time to work all the bugs out of the software. This had an adverse impact on SDRC's sales for 1993 and once again the company's stock took a hit. After recovering to about $19 per share, the sales shortfall knocked the stock down 28 percent to $13.75 in one day before it began recovering again.

With the introduction of Master Series, IBM dropped the CAEDS nomenclature for the SDRC software it was reselling and decided to market it as I-DEAS Master Series.

[21] *Engineering Automation Report*, April 1993, Pg. 3

At AUTOFACT '93 in Chicago, IBM demonstrated the software running on the PowerPC-based POWERstation 250.

SDRC was also starting to gain some traction selling PDM software. Towards the end of 1993 it closed a $2.3 million order for DMCS software and related services with European-based Groupe Schneider. The interesting aspect of this order was that Groupe Schneider used non-SDRC software, particularly PTC's Pro/ENGINEER, for its design work. This was one of the first installations of heterogeneous design and engineering information management software, a trend that would take on increasing importance for SDRC in the future. Overall, SDRC ending 1993 with revenues of $186 million for the year. As with the 1991 and 1992, these figures would soon be restated.

**Cooking the books**

As 1994 began to unfold, SDRC's revenues began improving modestly as the company closed several large orders in the Far East. Meanwhile the company closed an initial $8 million deal with Boeing for Metaphase PDM software. This was the calm before the storm. In September 1994 the company announced that it would be restating its revenues and earning for 1992 through the first half of 1994 to include a $30 million charge relating to sales discrepancies in its Asian operations. The company claimed that it first realized that there was a problem in August 1994 when a shortfall in cash collections resulted in the substantial write off of outstanding accounts receivable. It seems that the company's Far Eastern Operation had been booking orders that were not, in fact, valid sales.

The company immediately terminated Tony Tolani, a vice president and general manager of SDRC's Far Eastern Operations. He had been with the company for 21 years and headed this sales activity since 1988. SDRC announced that it would change how business in the region would be handled in the future. Retroactive to the beginning of 1994, the company would recognize revenue when a distributor sold a product to an end user, not when the product was shipped to the distributor. SDRC was not the first high tech company tripped up by this issue nor would it be the last.

Once again the company's stock was hammered, dropping 36% to $4.875 on 11 million shares trading in one day. This was the equivalent to nearly one third of the company's outstanding shares. A stockholder lawsuit was filed within 24 hours. The company had gotten a similar lawsuit filed earlier dismissed by the courts. The attitude seemed to be that the problem was not limited to Tolani. The lawyer bringing the latest lawsuit, William Flynn, was quoted as saying: "It begs the question to say that this is a management problem. This doesn't go on for 2½ years without it permeating all levels of management."[22] This time SDRC would not be as lucky in court nor would Tolani be the last of the company's management to go because of this problem.[23] Within a few months those exiting included Ron Friedsam, the company's CEO and Ronald Hoffman, the company's CFO.

Meanwhile the company's software kept moving forward. In late September 1994 SDRC announced Metaphase Series 2, the latest PDM software developed by Metaphase Technology. It included workflow management, product structure definition, application encapsulation, configuration management and component imaging.

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[22] *The Cincinnati Enquirer*, September 16, 1994

[23] *Engineering Automation Report*, October 1994, Pg. 3

As if the financial problems weren't enough, towards the end of 1994 SDRC was sued by Ashlar over the technology used in the company's Dynamic Navigator software. Ashlar claimed that SDRC's use of these techniques violated patents based on work done by Dr. Martin Newall, Ashlar's chairman and chief technology officer. The courts eventually ruled in SDRC's favor in September 1997 based upon the fact that Ashlar had demonstrated its technology more than a year before it filed its patent application, making the patent invalid.

**Getting the train back on the tracks**

In early 1995, SDRC released I-DEAS Master Series 2 with improved modeling capabilities, an improved user interface with more extensive use of the Dynamic Navigator in spite of the pending lawsuit with Ashlar and improved performance, particularly for viewing complex hidden-line images and part editing. At about the same time, the company announced restated revenues and earnings for 1991 through mid-1994. The changes were much more extensive than had originally been contemplated.

| Period | Original Reported Revenue (millions) | Restated Revenue (Millions) | Original Reported Net Earnings (Millions) | Restated Net Earnings (Million) |
|---|---|---|---|---|
| 1991 | $146 | $130 | $17.9 | $9.3 |
| 1992 | $163 | $149 | $14.5 | $9.5 |
| 1993 | $186 | $148 | $14.3 | ($11.7) |
| 1994 Q1 and Q2 | $101 | $80 | $6.4 | ($6.6) |

Overall, SDRC wiped $89 million in revenue off its books and reduced previously reported earnings by $31.4 million.

The company obviously needed some adult supervision and the board of directors asked one of the company's founders, Al Peter, to come back from retirement to take over the CEO position and get the train back on the tracks. Within a relatively few months, Peter had the company focused on improving I-DEAS Master Series' quality and functionality, improving its sales momentum and refocused on its analysis roots. In March 1995 I visited SDRC and spent some time with Peter, a low key engineering-centric individual who seemed somewhat out of place running a major software company. He was the complete opposite from the highly polished Ron Friedsam. But that was what the company needed in order to recover from its financial missteps.

I-DEAS Master Series 2 was a significant improvement over the company's initial release of this software. Specifically, SDRC worked closely with its user base to ensure that the software was stable before it was released. When Master Series was launched in mid-1993, individual software modules were tested fairly thoroughly but the testing of a fully integrated system working on complex designs did not receive adequate attention. The focus was to ship the software since revenue growth depended upon sales of the new product. With a conservative engineer running the show this time, SDRC was not about to make the same mistake twice.

While the software's geometric modeling capabilities were improved it was the package's user interface that really impressed me. Icon menus typically were only two levels deep compared to five and six levels in other systems, the Dynamic Navigator had been enhanced, users could define geometry working with shaded images of models, and commands such as DIMENSION worked based upon the context of the geometry selected (radial dimensions if it was a circle or arc). I wrote in the April 1995 issue of *EAReport:* "I-DEAS has the best interactive user interface available today for mechanical design and analysis."[24]

I-DEAS Master Series consisted of over 90 different modules that could be purchased either individually or as part of 28 different I-DEAS configurations. Prices typically ran from $16,000 to $35,000 per configuration with substantial quantity discounts. I-DEAS was supported on UNIX workstations from Digital, Sun, Hewlett-Packard, IBM and SGI while Metaphase was supported on the same mix of platforms except for the Digital workstations and servers. While the Metaphase client software was also supported on Windows 3.1 PCs, SDRC was quiet about its plans concerning porting I-DEAS software to either Windows 95 or Windows NT.

The company also seemed to be making progress with the Metaphase product. In addition to being sold by SDRC and CDSI, Metaphase was also being incorporated into solutions sold by Alpherel, FORMTEK and Intergraph. SDRC management believed that the joint venture was investing three times the resources in software development than SDRC would have been able to do by itself. Another interesting aspect of the Metaphase story was that SDRC was not necessarily targeting just its own customers but was instead was attempting to sell this PDM solution to companies using other CAD systems. To avoid the appearance of a conflict of interest, SDRC had established a separate sales force to sell Metaphase.

*EAReport* concluded its review of SDRC with a fairly upbeat assessment of the company. "The new management is committed to running SDRC with greater focus on the needs of the user community and with less concern about the investment community."[25]

**Making progress**

With its new management firmly in place, SDRC started focusing on rebuilding its sales momentum. A $12 million contract was negotiated with Nissan for I-DEAS Master Series software and services over a three year period. Perhaps equally significant was an $800,000 contract with MEM, Ltd., a division of Delta Circuit Protection and Controls to replace installed seats of PTC's Pro/ENGINEER software. This company was quoted in the press release distributed by SDRC that it was easier to make changes using SDRC's variational geometry than it was using PTC's parametric technology.[26] Thompson Multimedia signed up for $3.7 million of I-DEAS over five years and Boeing committed to an additional $7 million of Metaphase 2 software and services.

By the fall of 1995, word within the CAD industry was that SDRC had won a heavily contested competition at Ford Motor to become that company's primary vendor of CAD/CAM technology. This was a $200 million contract when it finally closed in December. The good news was that this would mean significant revenue from Ford and its suppliers in coming year while the bad news was that Ford would put tremendous

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[24] *Engineering Automation Report*, April 1995, Pg. 6
[25] *Engineering Automation Report*, April 1995, Pg. 9
[26] *Engineering Automation Report*, May 1995, Pg. 12

pressure on SDRC to provide software specifically tailored to its needs. By March 1998, SDRC had over 160 people supporting the Ford contract.[27] This made many other users of I-DEAS software feel like second class citizens.

The lawsuits filed in mid-1994 over SDRC's need to restate its financial results were settled in late 1995 for $27.6 million, of which the company's insurance carriers paid $5 million.[28] On the positive side, growing sales of I-DEAS and Metaphase software was starting to impact the bottom line. For the last quarter of 1995, the company had revenues of $62.8 million and an operating profit of $8.3 million before special charges including the lawsuit settlement.

**Strengthening the product line**

In early 1996, SDRC moved to strengthen the NC portion of its I-DEAS product line by acquiring CAMAX Manufacturing Technologies for $30 million. CAMAX had previously acquired Point Control and that company's SmartCAM software product line. CAMAX's flagship product was called Camand and it was used extensively to machine stamping dies for the automotive industry. Both packages were surface geometry and wireframe oriented with the major difference being that Camand was targeted at UNIX users working on complex parts while SmartCAM was a PC product that was used by smaller firms on less complex parts. NC had been a weak aspect of SDRC's software product line for some time and the integration of CAMAX software was viewed as a good move.[29]

In April 1996, the company released I-DEAS Master Series 3 with improved modeling capabilities such the ability to handle intersecting fillets, new techniques for viewing and managing design history, improved capabilities for importing geometry from other systems and healing geometric discrepancies, better NC functionality and new visualization software based on a relationship previously established with Engineering Animation, Inc. Then, just six months later, SDRC released I-DEAS Master Series 4 with additional geometric modeling enhancements, direct export of I-DEAS data to the Camand NC software it had recently acquired and bi-directional sharing of model data with the Alias styling software sold by the Alias|Wavefront Division of SGI. The latter feature was probably driven by Ford Motor.

In late 1996 the company announced that it was looking for a new president and COO with the expectation that Al Peter would remain as chairman and CEO although several months later they revised this to say that the new person would also become the company's CEO.

On the negative side, the relationship between SDRC and Control Data System over the management of Metaphase was starting to show some strains. Since SDRC was responsible for two-thirds of Metaphase sales, the company felt that it should have a bigger say in both product development and marketing. The two companies were unsuccessful in establishing a single PDM sales and support organization and for the time being decided to proceed on their own.

Within a month the Metaphase situation change rather dramatically when SDRC announced that it was acquiring CDSI's 50 percent interest in Metaphase for $31 million.

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[27] SDRC Press Release dated March 26, 1998
[28] SDRC 1997 Annual Report, Pg. 30
[29] *Engineering Automation Report*, February 1996, Pg. 14

That gave SDRC complete control over the 130-person Metaphase operation including both product development and marketing and in the long run proved to be a beneficial move.

**SDRC enters the mid-range fray**

By early 1997 it was becoming increasingly apparent that the new category of mid-range CAD software products such as SolidWorks, Solid Edge and Mechanical Desktop presented a competitive threat to the traditional CAD software product sold by vendors such as SDRC. In February SDRC announced I-DEAS Artisan Series, its first Windows NT product.

Artisan Series included most of the basic functionality contained in I-DEAS Master Series except for some of the latter's more advanced surface geometry capabilities. The basic software suite was called Artisan Series Modeler and it included solid modeling, assembly modeling, tolerance and mechanism analysis, drafting and a number of data translators, all for just $4,995. The industry's initial reaction was that this was a lot of software for a fairly reasonable price.

SDRC's plan was to attack the same market the other mid-range vendors were going after – the existing AutoCAD user base which was predominately drafting oriented at the time. Within this overall market, SDRC was particularly interested in the automotive sector which was then producing over a third of the company's revenues, up from just 10% two or three years earlier. Much of this was due to the company winning the major deal at Ford Motor. Artisan Series was expected to be particularly attractive to many of Ford's suppliers.

*EAReport* considered Artisan Series to be the most complete initial offering to date among the mid-range CAD products it had reviewed. Artisan Series Modeler incorporated the same Dynamic Navigator and lean menu structure (only two levels deep) that had impressed *EAReport* when it earlier reported on I-DEAS Master Series. Windows NT was the only operating system supported and there were no plans to provide this software on UNIX workstations or running under Windows 95. For the sake of compatibility, SDRC elected to stick with the traditional I-DEAS user interface rather than move to the Windows paradigm. According to Jeffrey Rowe, "While some users will find this Windows noncompliance somewhat bothersome, most will get over it quickly and get on with real work."[30]

The major problem any vendor of high-end solutions has when introducing a lower-priced product is how to maintain sales of the more expensive product. Clayton Christensen explores this problem in depth in his excellent book, *The Innovator's Dilemma*. Most companies try to establish artificial barriers around the lower-priced product and SDRC was no different in this situation. The company attempted to minimize conflict between the two product lines by marketing Artisan Series as an individual productivity tool while Master Series had built-in data sharing tools that facilitated concurrent engineering. This is similar to the strategy that Dassault Systemes eventually took with SolidWorks and UGS took with Solid Edge after these companies acquired those mid-range products.

In addition, while SDRC provided bi-directional transfer of geometric data, when going from Master Series to Artisan Series the model's history tree was not transferred. It

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[30] Rowe, Jeffrey, *Computer Graphics World*, June 1997, Pg. 97

was, however, transferred when going in the other direction. Licensing for the two product lines also differed significantly. Artisan Series was licensed for a specific computer system – what is usually referred to as "node locking." Master Series customers could procure floating licenses so that they needed to only install the maximum number of copies that would be in use at any one time rather than a copy for every potential user. Prices for Artisan Series software were not discountable while SDRC offered volume discounts for its other software. According to Bill Carrelli, SDRC's then vice president of field operations, "At some point, it actually becomes more economical to purchase Master Series. Typically , this will occur when there are 15 to 20 people in the design team." [31]

Artisan Series was intended to be sold exclusively through value-added resellers (VARs). SDRC claimed that it wanted to make it easy for an Artisan Series customer to upgrade to Master Series and offered a full trade-in on money spent of Artisan Series when a customer upgraded.

In early 1997, SDRC was doing well business-wise with revenues quickly approaching an annual rate of over $250 million.

**SDRC becomes a mature company**

Throughout the 1990s CAD software developers struggled to make it easier for a design engineer to edit a part or assembly model, particularly one which the engineer did not create himself. Far too often, using contemporary parametric design software was an exercise in frustration. Geometric elements needed to be related to each other in a very precise manner or changes could not be correctly executed. Designing a complex part was analogous to writing a computer program with the parameters taking the place of the program variables and the part's history tree taking the place of the software logic.

As part of its launch of I-DEAS Master Series 5 in mid-1997, SDRC introduced a new modeling technique it called VGX (extended variational technology). VGX was intended to bring to three-dimensional solids modeling what variational geometry had provided in the two-dimensional realm. It would eventually enable a user to change geometric entities without concern over the sequence in which they were initially created or subsequently modified.

According to Dr. Marc Halpern who was with D.H. Brown Associates at the time, "..VGX enables dramatic performance improvements in the ease of editing parametric feature-based solids because it removes the requirement of understanding and employing object history to make model changes."[32] Another way of putting it is that VGX made the model editing process much more natural. One of the advantages of variational geometry over pure parametric geometry is the ability to work with under-constrained models. Constraints can be added later, increasing the flexibility of the design process.

To some extent, this was more of a technology announcement than a fully functional capability. SDRC used Master Series 5 to launch the basic three-dimensional variational technology with plans for detailed capabilities to follow in future releases. The first version only worked with a limited set of extruded features. Master Series 5 had a number of other enhancements that made it an attractive design, analysis and manufacturing tool for complex parts and assemblies. Performance was once again

[31] *Engineering Automation Report*, March 1997, Pg. 1
[32] *Engineering Automation Report*, June 1997, Pg. 5

improved, on-line help, on-line tutorials and computer-based training made the package easier to lean and use, Web browsers could be used to view I-DEAS models, Metaphase was more tightly integrated with I-DEAS, the company placed renewed emphasis on analysis modules and the first steps were being taken to integrate the CAMAX software with I-DEAS.

*EAReport* concluded its review of I-DEAS Master Series 5 with:

> "We are impressed by the speed with which SDRC is improving its product line. The only thing preventing the company from giving Parametric Technology a run for its money is the lack of an aggressive sales force comparable in numbers and focus to what PTC brings to the table. SDRC is looking for a new CEO and if that person is capable of lighting a fire under this organization, the result could be impressive."[33]

SDRC solved its search for a new CEO in June 1997 when Al Peter retired once again and Bill Weyand took over as president and CEO. (He became chairman in February 1998.) Weyand had been executive vice president at Measurex, a company that provides control systems for the paper and process industries. Although he did not come from a CAD-related company, Weyand had a strong technical background associated with working for a computer-oriented vendor selling to industrial customers.

In late 1997 SDRC announced plans to acquire two privately held companies which did business together as Computer Aided Systems for Engineering (CASE) for 1.5 million shares of the company's stock then valued at $25 million. CASE had been responsible for developing several I-DEAS modules including Drafting, View and Markup and CADAM Translator with SDRC being the sole distributor of this software. The relationship had started in 1984 with the development of GEODRAW. From a financial point of view, this acquisition had no impact on SDRC's revenues but it improved the company profits since SDRC no longer had to pay royalties to CASE.[34]

**Expanding the product line**

Product enhancements at SDRC were starting to come fast and furious with significant I-DEAS releases approximately every six to nine months. In March 1998 SDRC announced I-DEAS Master Series 6 with enhancements focused on four areas - assembly modeling, analysis, manufacturing and collaborative design. Master Series 6 also extended the VGX technology described above to encompass assemblies as well as individual parts, making assembly design a logical extension of part design. As the user moved parts together, graphical feedback showed if the parts were parallel, tangent, perpendicular, etc. Built in mechanism animation eliminated the need for third party kinematics software.

Two significant analysis problems were addressed in Master Series 6 - suppressing small details that do not have to be considered by the analysis software and cleaning up surface geometry elements that could distort results. Previously, individual details were suppressed on a case by case basis, a rather time-consuming process. The

[33] *Engineering Automation Report*, June 1997, Pg. 9
[34] *Engineering Automation Report*, January 1998, Pg. 15

 

new software enabled the user to suppress all small details in a general area in a single operation.

Contemporary modeling techniques created extremely complex surfaces on solid objects which could result in small slivers of geometry. Finite element modeling software typically created nodes along each edge of a surface which might not have accurately represented the model for the purposes of analysis. Master Series 6 treated these surfaces in a more holistic manner, resulting in smaller FEA models and, according to the company, more accurate results.

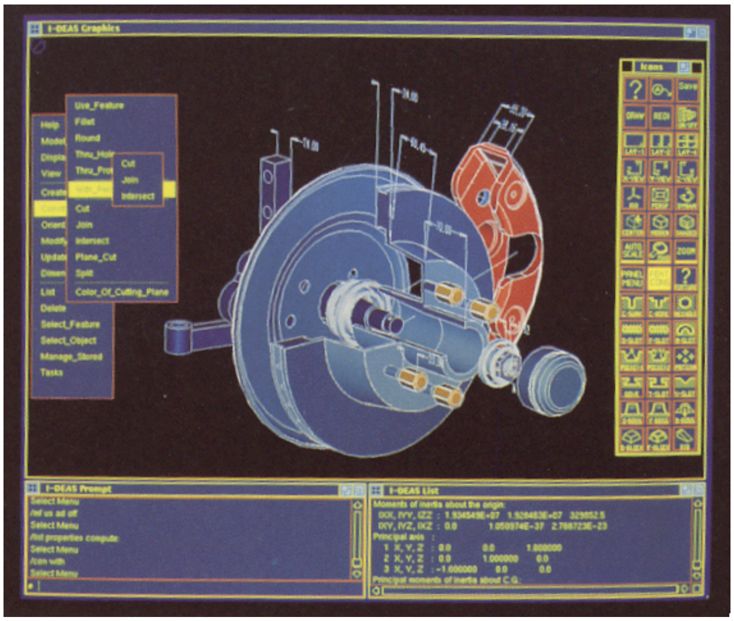

Figure 17.1
Typical I-DEAS Screen Image

In May 1998, *EAReport* carried an in-depth review of SDRC. In the process of preparing this article I once again visited Cincinnati and spent a fair amount of time with both Weyand and Carrelli. Weyand clearly saw the company's primary objective being the need to accelerate its growth. We discussed a number of inter-related steps being taken to accomplish this:

- The first step was to clearly define the company's market position. According to Carrelli, the company's then vice president of marketing, "We want to be the partner of choice for industry leading companies driven by time-to-market."
- It takes people to sell complex design and data management solutions. SDRC increased its field sales organization by 50 percent in 1997 and planed another 50 percent increase in 1998. Weyand expected this expanded team to start having a positive impact on sales by mid-1998.
- The company was committed to a 50/50 split between direct sales and resellers. They had taken steps to ensure that the company did not compete with

 

its own VARs. Basically, the SDRC people were responsible for specific designated accounts and the VARs were responsible for all other opportunities.

- During the prior three years SDRC's automotive business had gone from 15% of total revenues to over 40%. The company planed to exploit the position it had with Ford, Mazda, Nissan, and Renault and others by aggressively going after these companies' first and second tier suppliers. Other major markets were aerospace (19 percent) and consumer products (23 percent). The company's business was fairly evenly split between the United States (49 percent) and international (30 percent in Europe and 21 percent in Asia).
- SDRC's management recognized that there was a lot of confusion over the company's product nomenclature, Master Series, Artisan Series, etc.
- Finally, both Weyand and Carrelli discussed SDRC's need for greater visibility in the marketplace. Both felt that the company was winning a large portion of the deals where they were considered, but that SDRC was not always considered. To counter the lack of awareness, the company had launched a new marketing campaign targeted at top management with full page ads in the *Wall Street Journal* and several other leading business and trade publications that emphasized a new logo and the I-DEAS brand.

**Expanding its penetration of the automotive industry**

Many people in the CAD industry were surprised when Ford selected SDRC as its corporate standard for design and PDM software. SDRC was clearly the dark horse candidate when this procurement was underway. The resulting $200 million deal, however, seemed to be working well for both firms. As of the beginning of April 1998, Ford had installed 3,000 seats of I-DEAS and 2,600 seats of Metaphase Enterprise software. In addition, the company had shipped over 2,000 copies of I-DEAS to Ford suppliers. The contract with Ford included the requirement that SDRC sell copies of the I-DEAS software to these suppliers at a substantially discounted price. By the spring of 1998 Ford was using SDRC software to support over a dozen vehicle programs, a far faster ramp-up of the technology than what had been originally envisioned.

At this point in time, Ford was generating about 13% of SDRC's revenues. *EAReport's* observation was that this was a significant portion of the company's business, but not so large that other customers needed to be concerned that their needs were not being heard. It went on to say: "The bottom line is that SDRC cannot prosper by focusing just on Ford, but rather needs to use this as the prototype for additional major deals."[35]

Ford was in the midst of a major re-engineering initiative at the time called "Ford 2000" with multiple goals of reducing costs, enhancing product quality and reducing the time it took to develop a new vehicle from 42 months to just 20 months. SDRC had a project office at Ford staffed with 170 professionals whose aim was to help Ford accomplish these objectives. SDRC used the Ford project as the prototype of how it wanted to work with other large global manufacturers, particularly in the automotive sector.

[35] *Engineering Automation Report*, May 1998

 

A good example was the company's growing relationship with Nissan. In March 1995, Nissan and SDRC signed an agreement under which Nissan implemented I-DEAS Master Series for mechanical component design. In January 1998, the two companies expanded the relationship with a new $100 million multi-year agreement which extended the use of I-DEAS throughout the full design process, from concept and body in white to vehicle simulation and prototype production. Like Ford, Nissan used Metaphase Enterprise to manage product information.

In another deal, SDRC signed a contract for I-DEAS Master Series and Metaphase Enterprise with Renault in February that was expected to be worth more than $35 million over five years. This contract required SDRC to work closely with Matra Datavision which Renault had selected earlier to provide body design and manufacturing software.

**Improving Artisan interoperability**

By the fall of 1998 the battle for the mid-range CAD market was heating up considerably. SDRC had not made much of an impact in this area having sold just 2000 copies of I-DEAS Artisan Series in the 16 months since it was introduced. Its primary weakness appeared to be the lack of complete bi-directional compatibility with the company's high-end Master Series product. Master Series users were able to download models (including history tree information, feature definitions, constraints and parametric relationships) to Artisan but if changes were made to the model, only the basic geometry created in Artisan could be exported back to Master Series. This was an unacceptable limitation for large organizations that wanted the two software products to co-exist and work together.

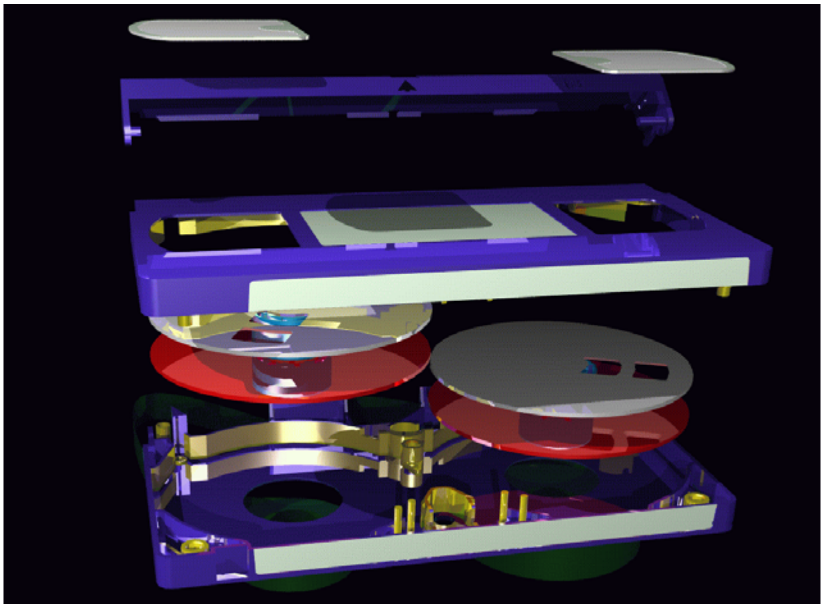

Figure 17.2
Exploded assembly model of a VHS videocassette created by Brian Slick of Purdue University using I-DEAS

 

When SDRC's customers made this point clear, the company responded with full bi-directional compatibility between Artisan and Master Series. There were still some functional differences between the two packages. Artisan Series 3 did not include some of the advanced surface geometry capabilities such as variational sweeps that were included in Master Series. Besides bi-directional compatibility, Artisan Series 3 also provided a complete drafting capability similar to that available with Master Series.

The prior versions had enough drafting to document Artisan designs but not enough to function effectively as a stand-alone drafting package. SDRC's sales strategy for Artisan changed somewhat since it had first been introduced. The company became increasingly focused on selling Artisan to existing large accounts and their primary suppliers in order to convert these two-dimensional drafting users to I-DEAS.

Bill Weyand, the company's new CEO, seemed to be having an impact on the SDRC's financial results. By the end of 1998, the company's annual revenues were running at more than $450 million and it was nicely profitable. As 1999 progressed, revenue growth slowed however and the company's stock took a big hit in October when it announced that revenues in the prior quarter had increased just 7 percent and earnings had dropped 64 percent from the comparable quarter a year earlier. It is interesting to note that the SDRC's mechanical engineering consulting business had shrunk to the point where the company no longer reported it as a separate line item. It was simply lumped in with other service revenue.

In October 1998 SDRC acquired privately-held Imageware Corporation of Ann Arbor, Michigan, for approximately $31 million in cash. Imageware was a specialty software firm that provided free form surface modeling software used extensively by the automotive industry and other companies to design Class 1 surfaces. Its customers included Mercedes-Benz, Volkswagen, Toyota, Ford Motor Co., Boeing, Lockheed-Martin, Motorola and Sony. On-going sales, however, failed to live up to what SDRC expected when it made the acquisition. While it initially continued to market Imageware software, by early 2001 it no longer sold that software except as part of the I-DEAS product line.[36]

**Expanding SDRC's PDM presence**

Sherpa Systems was one of the pioneers in the area of engineering document management and product data management. The company struggled throughout the 1990s, especially after signing a very large contract with Hughes Aircraft that distracted the company's development staff from providing the software most potential customers wanted. In December 1998, Sherpa was acquired by Boston-based Inso Corporation, an electronic publisher, for $35 million.

In January 2000, SDRC announced that it was acquiring Sherpa Systems from Inso along with a software development group called Inso France Development. The latter organization was involved in XML technology and SDRC planned to utilize its expertise in making the company's Metaphase software more Internet friendly. This group also had expertise in developing lightweight user interfaces and Web publishing technology. SDRC paid about $9.7 million for Sherpa and Inso France Development.

The primary rationale behind the acquisition, however, was to gain access to Sherpa's customer base, a number of whom had 1,000 to 10,000 users. Sherpa's

[36] SDRC 2000 Annual Report, march 2001, Pg. 2

customers base of 90,000 users included Boeing, Thiokol, and Johnson Controls. The first two were also SDRC Metaphase customers. Since it was well known that Inso was interested in selling Sherpa, SDRC obviously did not want to see competitors such as MatrixOne, PTC or Unigraphics Solutions gain a foothold at these accounts.

Combining the Sherpa customers with the 250,000 seats of Metaphase SDRC already had installed, the company now had about a 40 percent share of the installed PDM market. While SDRC stated that it would continue to maintain the Sherpa software, it was obvious to all parties that the company planned to migrate these accounts to Metaphase as soon as feasible. In early 2001, SDRC made it official that it would no longer enhance the Sherpa software.[37]

One of the major user acceptance problems surrounding the PDM market was the difficulty companies were having installing complex software. While CAD/CAM packages could pretty much be used as delivered, PDM software typically required substantial customization. SDRC attempted to get around this problem by marketing Metaphase Express, a set of Metaphase software modules and pre-defined services at a set price. The company had developed industry-specific templates to facilitate this process.

Complementing its Metaphase product line, SDRC introduced an e-business software product called Accelis in March 2000 that enabled users to access data from different enterprise application systems and present this data to users throughout an organization. In effect, Accelis was a Web-centric integration framework for linking different data sources. Several Metaphase customers including Boeing and Alstrom Power were quick to add this new software to their PDM installations. While SDRC obviously wanted to see Accelis customers use this software with Metaphase, it was designed to work with PDM solutions from other vendors.

In July 1999 SDRC had acquired TD Technologies for $10.3 million in stock and stock options. TD had developed a product called Slate (System Level Automation Tool for Engineers) which SDRC planned to use to expand the PDM capabilities of Metaphase Enterprise. Sales of the Slate product, especially to the automotive industry, failed to live up to expectations, resulting in a $8.5 million write-down in 2000.[38] Also in 1999, the company acquired Enterprise Software Products Inc., the developer of FEMAP, a desktop FEM tool, for $15.5 million in cash.

## Close to the end

As the world was acclimating itself to the new millennium, SDRC began shipping the latest version of its software, I-DEAS 8 in the spring of 2000. With this release the distinctions between Master Series and Artisan were blurred as Artisan users could now access the same applications as Master Series users. Artisan now supported floating licenses and both versions used Team Data Management for work-in-progress PDM.

I-DEAS 8 had enhancements in areas such as geometric modeling, assembly management, integrated Imageware surface modeling software, faster finite element modeling and analysis and improved NC functionality. A new totally integrated drafting module, I-DEAS Master Drafting replaced the older I-DEAS Drafting Detail package.

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[37] SDRC 2000 Annual Report, march 2001, Pg. 2
[38] SDRC 2000 Annual Report, march 2001, Pg. 13

In May 2000, SDRC hired Glenn Wienkoop as president and chief operating officer, responsible for product development, marketing and acquisitions management. Prior to joining SDRC, Wienkoop had been executive vice president of Cognex Corporation. More significant, however, was that prior to Cognex, he had been a senior executive Measurex, the same company Bill Weyand worked for before he became SDRC's CEO.

Business wise, revenues in the second quarter of 2000 crept up by 6 percent to $118.1 million led by a 25 percent increase in Metaphase sales while earnings slipped by 24 percent to $8.2 million. The company landed several significant Metaphase orders during that quarter including Nissan ($4.3 million), Erickson ($3 million) and Renault. Although Metaphase sales were increasing (they made up 35 percent of the company's revenues in 2000), I-DEAS sales were starting to spiral downward.

Overall, the company did fairly well for the first few years after Weyand took over in 1997, but sales growth slowed significantly in 2000. Ford accounted for 14 percent of the company's revenue in 2000. The large loss for 2000 shown in the table below was primarily due to $47 million in special charges resulting from the acquisition of Sherpa, Imageware and TD Technologies. Without the restructuring charges, the company earned $18.6 million in 2000. Earnings in 1997 would have been $49 million except for a special charge related to the acquisition of the portion of Metaphase owned by CDSI.

| **Year** | **Revenue in Million $** | **Earnings in Million** $ |
|---|---|---|
| 1996 | $285 | $38 |
| 1997 | $351 | $30 |
| 1998 | $403 | $36 |
| 1999 | $442 | $28 |
| 2000 | $452 | ($28) |

**EDS Acquires SDRC**

SDRC's 2000 Annual Report, which was distributed to stockholder in March 2001, was fairly upbeat. It talked extensively about the company's collaborative product management initiative in which SDRC would bring together its mechanical CAD/CAM products, the Metaphase PDM software and new Internet-centric tools to address the entire product lifecycle management process. The report discussed a new collaborative product suite of software scheduled for introduction in June.

On May 23, 2001, EDS announced an agreement to purchase SDRC for approximately $950 million in cash, or $25 per share. Concurrent with that purchase, EDS also offered to buy the 14 percent of its UGS subsidiary that was publicly held. The two companies were combined under the UGS name and became EDS' fifth line of business. Rather than duplicate details here, see Chapter 19 for a detailed description of how the two companies were merged together under EDS and how I-DEAS was blended together with Unigraphics.

 

# Chapter 18

# SolidWorks

As much as any company in the CAD industry, SolidWorks was inspired by the vision of a single individual, Jon Hirschtick. He received both a BS and an MS degree in mechanical engineering from MIT in 1983 and subsequently worked at the MIT CAD Laboratory under Dr. David Gossard. Hirschtick had a strong entrepreneurial streak in him from an early age including a period as a self-employed magician during high school. While working at the CAD Laboratory, he enrolled in an entrepreneurship class in 1987 where he teamed up with Axel Bichara to write a business plan for a new CAD software company they called Premise. Bichara was a graduate student from Germany who was also working at the CAD Laboratory at the time.[1]

The class business plan for Premise was submitted in mid-May, 1987 and in a little over a month the two founders had $1.5 million in venture funding from Harvard Management Company. It was no surprise that the company set up shop in Cambridge.

Figure 18.1
Jon Hirschtick[2]

Premise's initial software product, DesignView, was a two-dimension conceptual design tool that ran on IBM-compatible PCs and interfaced with Microsoft software packages such as Word and Excel. Users could sketch geometry, assign constraints and define dimensional relationships. If a dimension changed, the design would adapt to this new information. Since it could be interfaced to Excel, spreadsheets could be used to

[1] Bygrave, William D. and D'Heilly, Dan – editors, *The Portable MBA in Entrepreneurship Case Studies*, Pg. 81
[2] http://www.cs.technion.ac.il/news/2005/119/photos/11/

define parts by linking specific dimensions to cells in the spreadsheet. Design View sold for $1,895 per copy.[3]

While the software was successful in what it did, the market for DesignView was simply too small for Premise to prosper. Computervision acquired Premise and the DesignView software in the spring of 1991 with the intent of marketing DesignView as a conceptual front end to its own CADDS 5 software. Both Hirshtick and Bichara joined Computervision's management team. Bichera left after about a year to return to Europe where he enrolled in an MBA program at INSEAD in Fontainebleau, France. For the next several years, Hirschtick stayed with Computervision, initially managing DesignView and subsequently responsible for the product definition of other Computervision software.

**Getting started as Winchester Design**

Hirschtick left Computervision in August 1993 without a clear idea of what he wanted to do next other than run his own company. By January 1994, the idea of creating a low-cost desktop design system based on solids modeling technology began to jell. Hirschtick put together a team consisting of Bob Zuffante, Scott Harris, Constantine Dokos, Tommy Li and himself that started the development of what eventually became SolidWorks.

The founders decided to forego early external funding and worked out of their homes for much of 1994 without pay. They even purchased their own PCs to use for software development. A key addition to the team was Michael Payne who joined the group in August 1994 to manage the overall software development effort. Payne had been PTC's employee number three and was vice president of development when he left a few months earlier over a management dispute. Prior to PTC, he had been director of CAD development at Prime Computer. Anyone who knows both Hirschtick and Payne probably cannot envision two more distinctly different personalities, yet they worked effectively together for the next six years. The company was initially known as Winchester Design Systems, the name coming from where their first real office was located

With Payne on board, the company felt that it was time to acquire external funding. Hirschtick had been working closely on this issue with Bichara, who had returned to Boston and was working at Atlas Venture, a local venture capital firm. In fairly short order two other venture capital firms, North Bridge Venture Partners and Burr, Egan, Deleage & Company, joined Atlas Venture and the three provided about $4.5 million in funding.. This investment kept the company going until late 1995 when the same VC firms along with Kubota and other investors put an additional $9.2 million into the company. As part of this latter investment, Kubota became the company's distributor for Japan.

Another key recruit was Victor Leventhal who came on board in October 1994. Leventhal had had a long sales and marketing career with IBM where he had run a $1B division in the 1970s and early 1980s, had run a $120 million direct sales operation at Computerland and was the CEO of a CAD reseller, CAD Solutions, when recruited by Hirschtick. Leventhal's responsibility as chief operating officer was to build a reseller channel that was capable of competing with Autodesk's dealers.

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[3] *Computer Aided Design Report*, December 1988, Pg. 12

As discussed in Chapter 16, Parametric Technology Corporation, which was started in 1984, had been successful in part because it did not have to support the legacy minicomputer and mainframe-based software that its competitors did. PTC developed Pro/ENGINEER from the start to be hosted on networked UNIX workstations. Its software was written in a higher level language and the system utilized the latest software architecture techniques. But even PTC was limited in the extent the it could use platform-specific operating system code to implement user interface and file management tasks due to the multiple UNIX platforms it was committed to support.

Hirschtick's plan was very simple. SolidWorks would only run on Windows-based PCs and the company planned to utilize standard Windows capabilities for as many system functions as possible. The result was a program that had the same Windows look and feel as Microsoft's own applications including Word and Excel. This approach significantly reduce the amount of software code that Payne and his development team had to produce. Also, if the software was to run on inexpensive PCs, then the price of the software had to be similar. The company settled on $3,995 for the initial release.

As reported in the October 1995 issue of the *Computer Aided Design Report*: "What distinguishes this CAD software from others is the way these capabilities are controlled by the user. Once you're familiar with the basics of Windows programs, it's much easier to create and change parts and assemblies than is possible with any other solids-based system we've seen."[4]

This strategy also took advantage of changes taking place in the PC world. Both Windows NT and Windows 95 were turning out to be well accepted by the user community, the performance of Intel microprocessors was increasing very rapidly and the price of memory decreasing at an even faster pace. As a result, fast PCs with large internal memories were becoming economically attractive.

**Early versions of SolidWorks[5]**

SolidWorks, while still known as Winchester Design, began quietly showing a prototype of the SolidWorks software to industry analysts and media in late 1994. I believe I first saw the software at the National Design Engineering Show in Chicago in February 1995. This was followed up in late summer by a visit by Jon Hirschtick to *Engineering Automation Report's* office in Englewood, Colorado where he personally demonstrated the latest pre-release version of the software.

Hirschtick did a competent job of building individual part models with the software but when I asked that he create a simple assembly, the software failed to cooperate. I never could determine if there was a software problem or Hirschtick was simply not proficient with the assembly functions in SolidWorks.

Initial development used Spatial Technology's ACIS geometric kernel but long before the software was released the company switched to EDS Unigraphics' Parasolid due to performance problems and functional deficiencies with ACIS. EDS also offered SolidWorks better licensing terms than did Spatial.

Shortly before the software was to be released, PTC filed a lawsuit against SolidWorks claiming that the latter company had recruited PTC employees in violation of

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[4] *Computer Aided Design Report*, October 1995, Pg. 5

[5] I did some consulting for SolidWorks about this time, particularly putting together a white paper that put forth the proposition that SolidWorks was the natural evolution of CAD software.

 

those employees' non-compete agreements. This could have stalled SolidWorks dead in its tracks but the two companies managed to settle before too much damage was done. It did set the stage for the fierce competition between the two companies that persists to this day.

The formal unveiling of the software, now known as SolidWorks 95, took place at the 1995 AUTOFACT conference. There was no question from the start that one of SolidWorks' target markets consisted of companies that were considering the purchase of Pro/ENGINEER software. The other competition, of course, was Autodesk and its AutoCAD software. (See Chapter 8.)

SolidWorks 95 was a feature-based, dimension-driven solids modeler that generated two-dimensional drawings directly from the solid model. As with Pro/ENGINEER, a change to the model changed the relevant drawings and going the other way, a change to the drawing was also associated with the model. While a surprising amount of Pro/ENGINEER-like functionality was incorporated into the first release of SolidWorks, there were some differences. Some of these involved modeling capabilities that probably were of interest to a minority of potential customers while other were more strategic in nature. Foreign drafting standards were not supported initially which slowed down the software's acceptance internationally.

On the flip side, the initial implementation of SolidWorks 95 incorporated features normally associated with more expensive high-end systems. This included the ability to name specific features rather than just numbering them, the ability to use sketches that were not fully constrained and the re-ordering of features using the same technique one would use to reorganize Windows files within a folder or between folders.[6] Models could incorporate algebraic relationships between dimensions so that a change to one dimension could change one or more other dimensions. Other aspects of this new package that appealed to prospects were:

- A graphical user interface compatible with Windows 95 and Windows NT
- A sketcher that automatically applied constraints
- OLE 2.0 enabled files for exchanging model data with other applications
- A constraint manager based on the DCM software from D-Cubed
- The ability to reposition a feature by simply selecting it and dragging it to a new location
- The ability for users to create their own macro commands using the BASIC programming language.[7]

SolidWorks 95 took off with a bang. Most initial releases of new software products have severe functional shortcomings and far too many bugs that prevent productive work from getting done. Not so with SolidWorks 95. According to *Computer Aided Design Report*: "We're pleased to report that SolidWorks is one of the nicest – possibly the best ever – first release of a CAD software product that we've seen." The newsletter went on to extol the software's modeling capabilities, particularly its "Feature Manager" which enabled users to change the sequence in which a model was regenerated or "rebuilt" in SolidWorks terminology. The nested list of elements used to create the

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[6] *Computer Aided Design Report*, October 1995, Pg. 5
[7] *Engineering Automation Report*, October 1995, Pg. 6

 

design were displayed on the side of the screen at the same time the model was being viewed.

There were some problems with the early software, particularly in the area of assembly modeling and drawing production. Assembly modeling functionality was somewhat limited and if you were not careful, you could insert one part into another. While drafting was judged to be a good start, there were a number of limitations that required workarounds. The *CAD Report*, was also disappointed with overall performance on mid-range PCs, particularly in regards to photorealistic rendering using PhotoWorks described below. Documentation, or the lack thereof, was also a concern.[8] Most of these complaints were of the type that one could expect to be corrected with the next several releases of the software and they were for the most part.

**Jumping on the bandwagon**

Fairly early, SolidWorks made it clear to the rest of the CAD industry that it would not develop a direct sales force to compete with its resellers. This resulted in a highly committed group of dealers. Likewise, the company indicated that it planned to focus on the core SolidWorks software and would not be developing a broad spectrum of applications. This position appealed to independent software developers and soon a number of them were offering applications that worked with SolidWorks. In some cases, SolidWorks bundled these application with its own software and sold them as a package while in other cases, SolidWorks took a hands off approach.

One of the first applications was a photorealistic rendering package, PhotoWorks, developed by LightWorks Design of Sheffield, England. It was sold by SolidWorks for $795 or customers could buy the combination of SolidWorks and LightWorks for $4,390.[9] By mid-1996, SolidWorks had signed partnership agreements with 55 third-party software developers, seven of whom had already released SolidWorks compatible packages.

One of the most aggressive of these partners was Los Angeles based Structural Research and Analysis Corporation (SRAC). Founded by Dr. Victor Weingarten, SRAC was a vendor of moderately priced finite element analysis software that was reasonably easy to use and quite fast, at least for small to moderate size problems. SRAC repackaged its COSMOS FEA software to work directly with SolidWorks 96. Called COSMOS/Works, it added a FEM menu item to the top of the SolidWorks display. When selected, this menu item took the user out of SolidWorks and into a version of COSMOS tailored specifically to work with SolidWorks model data.

Users were able to create a FEA model from the SolidWorks model, apply loads and boundary conditions, analyze the part and view the results. Both programs had a similar look and feel that conformed to the Windows standards. The intent of this implementation was that a design engineer would be able to do his/her own stress analysis rather than have to involve a structural analysis department staffed with FEA specialists who used high-end FEA software such as ANSYS or MSC NASTRAN on mainframe computers.

This created heated discussions within the engineering community as analysis professionals felt that providing this capability to engineers who lacked sufficient training

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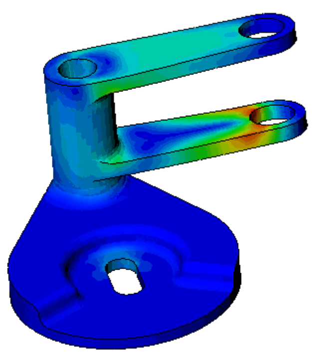
[8] *Computer Aided Design Report*, April 1996, Pg. 3
[9] *Computer Aided Design Report*, March 1996, Pg. 12

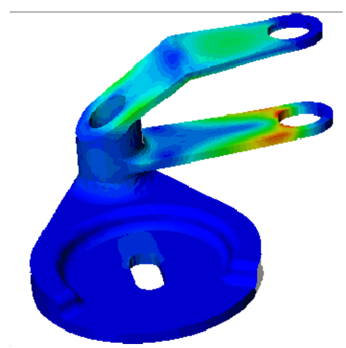
was a dangerous precedent while the proponents of this approach felt that it would now be possible to analyze far more parts than before and under a greater variety of conditions. There probably was some truth to both sides of the argument.[10]

As with SolidWorks itself, one of the key technology developments powering the increased use of advanced technical software was the rapid increase in computer performance, especially desktop PCs. By late 1998 many engineers had access to 400-MHz Pentium II computers for their own use. These machines were capable of analyzing large FEA models that just a few years earlier would have required a mainframe computer. As an example, one SRAC customer, Nichols Aircraft, built an FEA model of one of its jet engine lubricating oil pumps that had 1.3 million degrees of freedom. It took just two hours to run an analysis on a contemporary PC. Between them, SolidWorks and SRAC were changing the practice of engineering design and analysis.

Although SRAC worked with other CAD vendors including Intergraph and UGS, its relationship with SolidWorks was perhaps the strongest and the most tightly integrated version of its software was COSMOS/Works. COSMOS/Works 99 added design optimization capabilities to this product as shown in Figure 18.2.



Original Design



Optimized Design

Figure 18.2
COSMOS/Works Design Optimization Software

**SolidWorks evolves at a fast pace**

SolidWorks 96 was released in July 1996 with fixes to many of the early problems mentioned above. In particular, assembly modeling was beefed up significantly. User were now able to design and edit individual parts while in assembly mode. The performance regarding large assemblies was improved by enabling users to load subsets of the models they wished to work with. Drafting was also improved by providing users with more control over the placement of individual views as well as the ability to use three different line weights and multiple text fonts.

Assembly cross sections worked much better than with the initial release of the software. Documentation was substantially improved and rendering performance was more acceptable. There were still some shortcomings that had not been fixed such as the

[10] *Computer Aided Design Report*, November 1996, Pg. 7

lack of a redo function and the inability to stop long operations such as loading large models by mistake.[11]

Less than a year later, SolidWorks 97 was rolled out with 175 enhancements according to the company. This version of the software incorporated a number of enhancements and corrected problems associated with the first two releases. A new sheet-metal design capability was incorporated into the basic package as was the ability to add raised text to flat surfaces of parts. Thin shell objects could now have more than one thickness.

SolidWorks also beefed up the software's ability to do assembly modeling as well as its drafting capabilities. Although the software still had some aggravating problems and the on-line documentation left much to be desired, in the 14 months since SolidWorks first shipped, it had been improved substantially.

In fact, the rapid increase in functionality was starting to concern some industry analysts. Steve Wolfe covered this in the February 1997 issue of *Computer Aided Design Report*.

> ".. as SolidWorks expands the capabilities of its software, it runs the risk of making it too complex for most designers to learn. That complexity might be all right for products that cost a great deal and are used only by experienced specialists, but it won't do for a product that is attempting to broaden the base of three-D designers.
>
> "A second question for SolidWorks managers and users to ponder is which functions belong in the basic product and which should be included in specialty applications. The addition of sheet-metal design is a good example. Not all products incorporate sheet metal. Adding sheet-metal development to the basic product makes it more complex. In SolidWorks 97, the sheet-metal design controls are simple and don't get in the way. But as sheet-metal designers demand more automation, the complexity will increase and so will the user-interface clutter. If other manufacturing applications are added, the complexity of SolidWorks will grow geometrically."[12]

Meanwhile, the war of words between Parametric Technology Corporation and SolidWorks was starting to heat up. As discussed in Chapter 16, Steve Walske, PTC's CEO, did not feel that a real market existed for what was starting to be referred to as "mid-range" CAD solutions. At an analyst meeting in early 1997 Walske commented: "Low-end products are flawed because they can't design a meaningful portion of the mechanical marketplace."[13] That may have been true a few years earlier but by 1997, that was no longer the case.

**Dassault Systemes acquires SolidWorks**

In a move that surprised everyone not involved in the discussions, Dassault Systems announced on June 24, 1997 that it was acquiring SolidWorks for $300 million

[11] *Computer Aided Design Report*, August 1996, Pg. 7
[12] *Computer Aided Design Report*, February 1997, Pg. 3
[13] *Computer Aided Design Report*, February 1997, Pg. 3

or about 12 times the company's annual revenue. In a call from Paris late that night, Jon Hirschtick reminded me that in *Engineering Automation Report*'s first article on his company less than two years earlier, in October, 1995, I had written, "SolidWorks will have the most significant impact on the mechanical design market in nearly a decade." Little did I expect that impact to come quite so quickly. There had been many acquisitions in the CAD/CAM industry during the prior 25 years, nearly all of which involved a company in trouble being acquired by a stronger player. This was one of the first that involved the merger of two strong companies. [14]

At the time of the announcement, SolidWorks had sold about 6,000 copies of its software. Several points concerning the acquisition were immediately made clear. First, and most important, SolidWorks would continue to function as an independent organization controlling its own product development strategy. Second, the SolidWorks package would continue to be sold by the existing reseller channel and not by IBM which sold the bulk of Dassault's CATIA software. Third, SolidWorks would continue to work cooperatively with third-party software vendors. A decade later, this still holds.

The results of most acquisitions in the CAD industry have ranged from poor to terrible. Making an acquisition in order to increase the size of one's customer base has generally proven to a mistake. Dassault's acquisition of SolidWorks seems to have worked from the start because there was little market overlap between the two firms and Dassault proceeded to keep it that way. Dassault's CAD business tended to be with large industrial concerns such as Boeing and Chrysler which had long term relationships with IBM as described in Chapter 13. SolidWorks customer base consisted primarily of smaller companies that flew under IBM's radar. At the time, Dassault did not have a Windows version of CATIA which was the only platform SolidWorks supported. Also, there was not a mindset of competing with CATIA at SolidWorks since the company was more focused on Pro/ENGINEER and AutoCAD.

While there has been a moderate amount of technology sharing between Dassault and SolidWorks over the years, for the most part the two parts of the company have continued to go their separate ways. SolidWorks still uses the Parasolid geometric kernel even after Dassault acquired Spatial and its ACIS technology in 2000. Core business functions like financial management were centralized while customer-related activity including product content and direction was independently managed.

**Competition with Autodesk**

Early 1998 was also the start of a more aggressive marketing war between SolidWorks and Autodesk. In general, SolidWorks was on a roll, both technically and marketing-wise while Autodesk was struggling to rationalize its mechanical product strategy. Under Vic Leventhal, SolidWorks had built an impressive distribution channel with many of its resellers either former or current Autodesk resellers.

Autodesk announced in early 1998 that resellers authorized to carry Mechanical Desktop could not also sell competitive products, especially SolidWorks. Several major resellers including U.S. CAD and Micro Engineering Solutions were subsequently terminated by Autodesk.

About the same time, in February 1998, SolidWorks became a founding member of the OpenDWG Alliance (known today as The Open Design Alliance). The intent of

[14] *Engineering Automation Report*, July 1997, Pg. 1

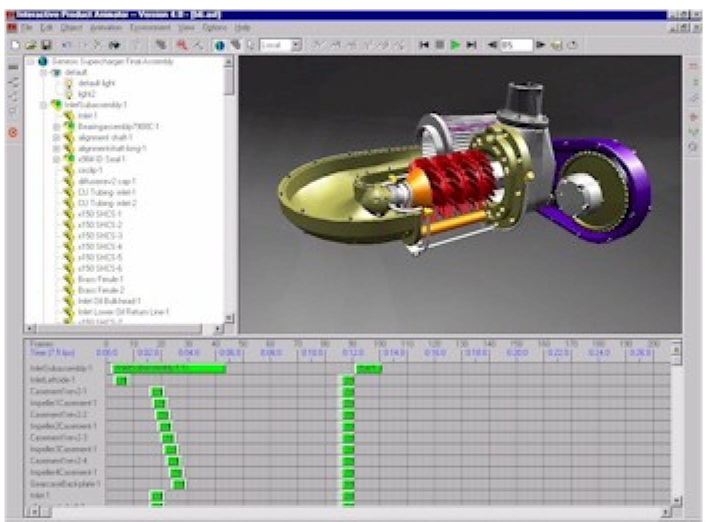
 

this industry group was to provide software tools that facilitated the direct reading and writing of AutoCAD files using Autodesk's internal DWG format.

Autodesk has never published a detailed description of the DWG format. As a result, programmers working under contract with the Alliance were forced to reverse engineer the file format. By joining the alliance, Autodesk competitors who wanted primarily to be able to quickly read AutoCAD files, could pool their development resources in this area and eliminate redundant development work.

**Third-Party software key to SolidWorks strategy**

For the next several years, SolidWorks delivered a new release of software about once a year. For the most part, the company focused on its core modeling and drafting technology leaving applications such as analysis, NC and PDM to third party vendors. As an example, even advanced surface geometry software was available from external sources. Aerohydro, of Southwest Harbor, Maine offered a program called Surface Works which had originally been developed to support the company's ship design activities. Another example was Immersive Design, located in Acton, Massachusetts. Founded in 1995 by Greg Smith, Immersive offered an animation and visualization package called Interactive Product Animator or IPA as shown in Figure 18.3.



**In this screen shot, imported data is stored and displayed hierarchically in the top left window while the bottom window shows the movement sequence spreadsheet.**

Figure 18.3
Immersive Design's Interactive Product Animator

SolidWorks established its Gold Partners Program to facilitate the development of these third party applications. The intent was to provide a consistent look and feel between the applications and the SolidWorks program itself. As an example, CosmosWorks structural analysis software appeared to a user as simply an extension of SolidWorks. If the user wanted to rotate a FEA model, he/she used the same pull-down menu that was used to rotate a SolidWorks model. In this manner, SolidWorks was able to present its software and that of its Gold Partners as an integrated solution with a common user interface much like that of its larger competitors and of Dassault Systemes for that matter.

At NDES ’97, ANSYS’ demonstrated its new DesignSpace application that wrapped their FEA program inside a SolidWorks compatible Windows interface. A four-step "Will it break?" wizard simplified the analysis process for design engineers by providing a green flag (okay) or red flag (start over) as part of the process’ output.

Although SolidWorks had fairly good drafting functionality, the company signed an agreement with Adra Systems in April 1997 to add that company’s Cadra Drafting software to its list of supported third-party packages along with a customized version of Adra’s PDM package, MatrixWorks. A few months later Adra Systems split into two companies, the original Adra Systems that continued to market the Cadra drafting software and MatrixOne that took over development and sales of the Matrix PDM software. In 2006, MatrixOne was acquired by Dassault Systèmes.

**SolidWorks becomes a serious design package**

One measure of good software architecture is the speed with which a major package can be enhanced without adversely impacting performance or reliability. Watching SolidWorks evolve over the years seems to confirm the quality of its underlying architecture. With SolidWorks 98, released in early 1998, the company added numerous enhancements that facilitated the creation of complex geometry, drawing generation and assembly modeling. The latter area was a subject most CAD vendors were still struggling with, particularly in regards to the initial loading and display of complex assemblies. SolidWorks 98 was able to display a 150-component assembly almost instantaneously.[15]

By early 1999 SolidWorks had installed over 20,000 seats of SolidWorks and was starting to pursue deals in the 1,000 seat range. Although Dassault did not publish SolidWorks-specific financial results, *Engineering Automation* Report estimated that SolidWorks was doing $40 to $50 million on an annualized basis. The company established a major accounts team to go after these large deals. These teams were responsible for coordinating the activities of dealers, third-party software firms and hardware vendors in pursuing this business but the actual purchases were still directed through the dealers. SolidWorks worked hard to create a more positive business environment for dealers than what those companies experienced with other software vendors such as PTC and Autodesk.

The mid-1999 launch of SolidWorks 99 included a new three-dimensional sketching capability that facilitated the introduction of a new piping module priced at $995 per copy.

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[15] *Engineering Automation Report*, March 1998, Pg. 12

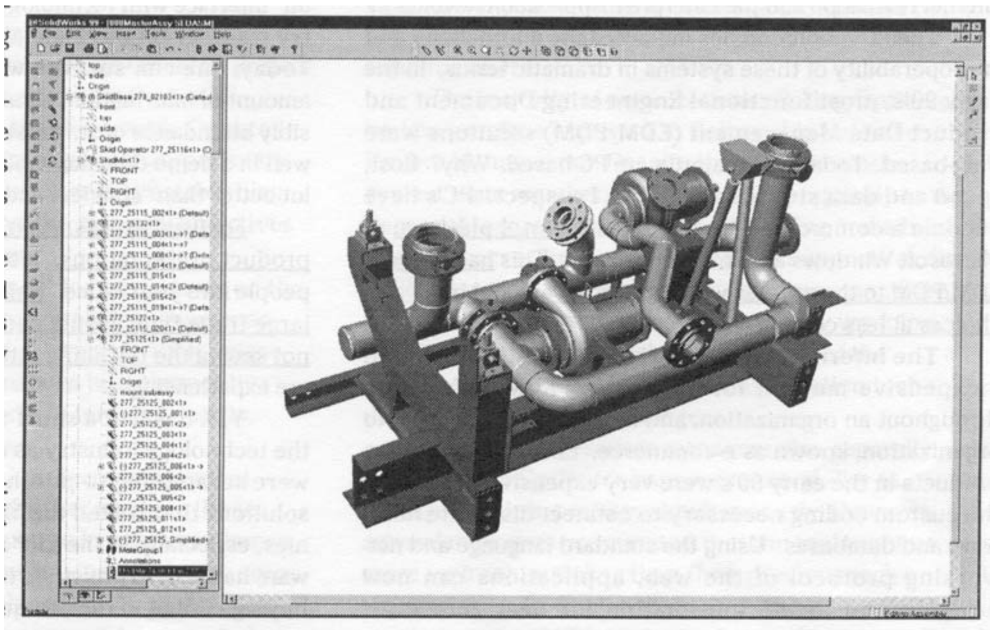

Figure 18.4
SolidWorks 99 Piping Design Module[16]

The company sold over 17,000 commercial seats of SolidWorks in 1999 for a total at the beginning of the new decade of about 43,000 seats. SolidWorks 99 was followed in early 2000 by SolidWorks 2000 with improved part modeling and drafting and speeded up assembly viewing. Users were particularly interested in improved assembly viewing speeds since the models being developed on these systems were getting bigger by the day and although computer power was also improving, much still needed to be done at the software level in order to keep assembly modeling from falling into disuse.

The one thing customers and prospects were not seeing was any effort to meld SolidWorks and CATIA, especially the new CATIA V5, into an integrated solution. Each system maintained its own development focus and sales appeared to target different segments of the market.

**Management changes start**

In the spring of 1999, Mike Payne, SolidWorks' executive vice president of research and development became executive vice president of technology for Dassault Systèmes. R&D management at SolidWorks was split between David Corcoran who took over the development group in Massachusetts and Linda Lokay who was responsible for a separate development team in Cambridge, England.

About the same time, Dassault acquired a 75 percent interest in Smart Solutions, an Israeli company that marketed a PDM system called SmarTeam. This package was particularly well suited to users of SolidWorks although the two Dassault subsidiaries operated independently of each other. The SolidWorks version of SmarTeam was called SmartWorks.

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[16] *Engineering Automation Report*, July 1999, Pg. 11

 

By the end of 1999, SolidWorks had become a very comprehensive geometric modeling tool with decent assembly modeling capabilities. In less than five years since its first release, this software was comparable in many regards to more expensive software products that had been around for a lot longer. The company was now big enough to be the target of recruiting raids launched by a new generation of startups.

One example of this new maturity was a temporary restraining order SolidWorks obtained against Alibre, Inc. in March 2000. The order prevented the relatively new CAD company from recruiting additional SolidWorks employees. Prior to the restraining order being issued, Alibre had lured Tom Kopinski, former director of North American sales for SolidWorks, to be its vice president of sales. Kopinski, like other SolidWorks employees, had an employment contract with SolidWorks that prevented him from joining competitors. As mentioned earlier, SolidWorks had been involved in a similar legal case when PTC complained about SolidWorks poaching its employees. [17]

In mid-2000, Dassault purchased the solids modeling component software business from Spatial Technology including the ACIS modeling kernel. Many people expected SolidWorks to switch from Parasolid to ACIS since Parasolid was controlled by a competitor to both SolidWorks and CATIA.

**eDrawings**

Probably starting in the mid-1980s, CAD advocates proposed doing away with traditional engineering drawings and using model images and digital data for construction and manufacturing. Most of these pioneers were ahead of their times but gradually, drawings began to take a back seat to model data. By the late 1990s it was not at all uncommon for design groups to provide companies that were making dies, molds and other components with digital model data supported by a limited amount of two-dimensional drawings. As an example, complex surfaces are very difficult to accurately define on an engineering drawing but easy to transfer from one system to another using either native data or industry standard formats such as IGES and STEP. But there was still a need for drawings, if only they could be made more useful.

In late 1999, SolidWorks introduced a new type of computer generated drawing the company termed “eDrawings.” As shown in Figure 18.5, an eDrawing was derived from a three-dimensional model, but rather than just containing two-dimensional data it carried with it the underlying model information. There were two versions of eDrawings, one which included the viewing software as part of the drawing file and one which assumed the recipient had the viewing software loaded on the computer on which the drawing was to be viewed. Obviously, the latter file was more compact.

SolidWorks provided both the viewing software and the software necessary for creating eDrawings free of charge although there was some consideration of charging for the publishing software known as eDrawings Professional. Eventually, the company expanded this capability to handle drawings generated by competitive systems including AutoCAD, Inventor, Pro/ENGINEER, Solid Edge, Unigraphics and Dassault’s own CATIA V5.

[17] *Computer Aided Design Report*, April, 2000, Pg. 15

 

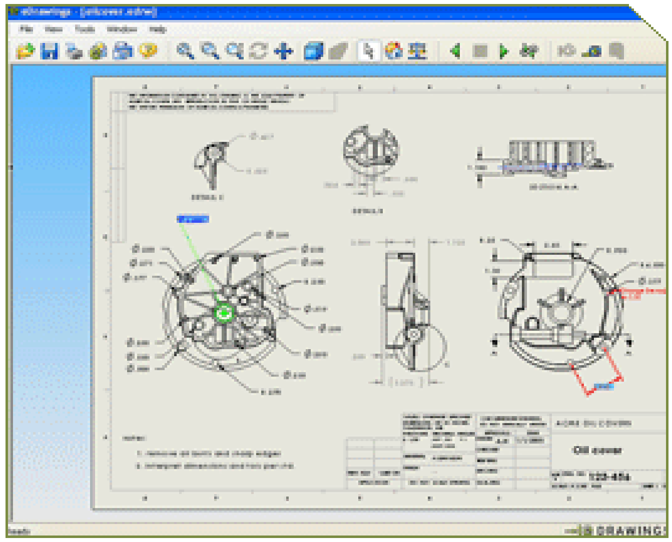

Figure 18.5
SolidWorks eDrawing

**SolidWorks reaches maturity**

SolidWorks 2001 probably defined a new level of maturity for this rapidly growing product. This release marked a new approach to the user interface that SolidWorks' marketing people called "Heads Up User Interaction." According to *Engineering Automation Report*:

> "Following a trend begun in SolidWorks 99, they've eliminated almost all dialog boxes. For example, when extruding entities, you can now assign values directly on screen, adjacent to the entities being extruded. The PropertyManager has now been implemented throughout the program, and context-sensitive callouts have been added. The latter appear within the model or drawing display to assist the designer. Context-sensitive callouts include symbolic sketch relation callouts as well as descriptive and editable feature callouts that display the appropriate design information, allowing the user to better understand and more easily modify designs. These callouts display information such as relationships on sketch entities, labels for feature inputs, or a method for changing feature parameters."

By late 2001, Dassault's acquisition of SolidWorks was looking very good. At a meeting held for the press and analysts at the company's Concord, Massachusetts headquarters in November 2001, SolidWorks executives were pleased with what the company had accomplished and optimistic about the future. Depending upon how one evaluated the numbers, SolidWorks could claim to be the leading vendor in the mid-range three-dimension CAD market, exceeding the revenue in this segment claimed by Autodesk.

 

The underlying theme of the meeting was that the target markets SolidWorks was pursuing were far from saturated and that there was still a large pent-up demand for three-dimensional design software within design organizations that were still using two-dimensional tools.

Hirschtick and other SolidWorks participants in the meeting emphasized that SolidWorks was basically a CAD company focused on producing the best design software possible and that it was not a PLM company. Sales in 2001 were running 20 percent above those of 2000 with 70 percent of the revenue coming from new customers. This was an exceedingly high number when compared to the competition. For example, 90 percent of PTC’s revenue was coming from its installed base.

SolidWorks claimed that 50 percent of its new business was coming from existing Pro/ENGINEER accounts. At this point, SolidWorks had sold over 160,000 seats of software, 88,000 to commercial accounts and the balance to educational institutions. By the end of the year, SolidWorks represented just under 20 percent of Dassault Systems’ revenue as compared to just 2 percent when it was acquired.

One of the major problems experienced by all software companies with a large installed base of users was how to determine where to invest R&D resources. User group wish lists and focus groups help but are not a complete answer. SolidWorks used an interesting software tool to help gather information from users. This tool could be optionally initiated by the user and about 5 percent of them had done so at this point.

The software collected information about what functions individual users executed, how often the software was active and problems the users incurred. This information was collected and sent to SolidWorks via email every two weeks stripped of any customer-specific data. One interesting statistic was that in 2001 each SolidWorks license was being used 550 hours annually compared to 450 hours in 2000. Not only were there more licenses in use, but each license was being used more intensely.[18]

**A changing of the guard**

A few days after the press and analyst meeting, the company announced on November 9, 2001 that its founder and CEO, Jon Hirschtick, had decided to step down. John McEleney, formerly the company’s Chief Operating Officer, was promoted to the CEO position, effective immediately. McEleney was a five-year SolidWorks veteran who had built the company’s profitable partnership and subscription service programs and its Pacific Rim sales channel.

The change in leadership was not a complete surprise. For the prior three months Hirschtick had been on sabbatical and McEleney had been running the company. Hirschtick cited two factors in making his decision: personal and family concerns and a desire to position the company’s management team “to continue to achieve the phenomenal success that our company has experienced over the last eight years.”[19]

Hirschtick assumed a new role as group executive for SolidWorks at parent company Dassault Systèmes. He also continued in his role as a member of the board of directors of SolidWorks. *Engineering Automation Report* viewed this change favorably:

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[18] *Engineering Automation Report*, December 2001, Pg. 1
[19] SolidWorks press release, December 9, 2001

"Our view on this is positive. Jon will remain involved with the company doing what he does best, which is providing guidance and vision. McEleney gets the title to go with the responsibility he's had for a long time – he's been doing an excellent job running the company and he deserves the CEO title. Jon gets to enjoy his children and focus on the long-term vision of the company. Everybody wins, especially the customer."[20]

December 2001 also marked the introduction of SolidWorks 2001 Plus, the company's tenth major software release. One significant addition was the use of Assembly Engineering Manager software from D-Cubed. The two companies had been working together to create software that would enable users to simulate true motion between solid components. SolidWorks 2001 also incorporated software that facilitated the design of assemblies where part mating conditions were critical to the operation of the product. There were also enhancements to drafting functions as shown in Figure 18.6.

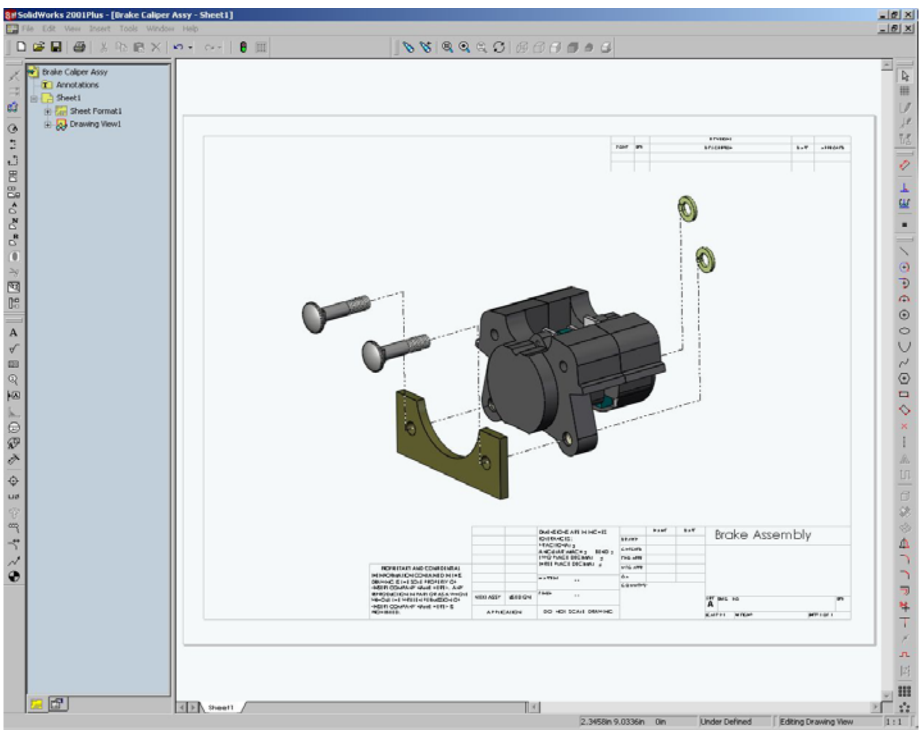


Figure 18.6
Improved Exploded Views with Optional Shaded Edges in SolidWorks 2001[21]

A major marketing strategy at SolidWorks was the need for users of two-dimensional drafting software, particularly AutoCAD, to move to three-dimensional model-centric design. Until SolidWorks 2001 Plus, the company had not done much to help customers actually make the transition. SolidWorks 2001 Plus added several tools

[20] *Engineering Automation Report*, December 2001, Pg. 3
[21] *Engineering Automation Report*, December 2001, Pg. 5

 

that facilitated the conversion of two-dimensional drawings into three-dimensional models. In effect, the user could place each two-dimensional view on the appropriate side of an imaginary glass box surrounding the implied three-dimensional model. A set of software tools could then be used to actually build the model from these views. One nice aspect of the software was as the model was rotated, the projected views moved with it.

**SolidWorks jumps into PDM fight**

By June 2002, it was clear that Dassault Systemes' acquisition of Smart Solutions was not working out as well as the company had expected. Some of the SmarTeam employees were transferred to Dassault's Enovia subsidiary, some to Dassault's professional services organization and other to SolidWorks. Although the company continued to sell SmarTeam to users of other CAD solutions, the bulk of the effort became the responsibility of SolidWorks which began marketing SmarTeam through its existing reseller channel. It was clear that SmarTeam was the preferred PDM product for medium and large users of SolidWorks.

A substantial portion of SolidWorks installed base consisted of installations with just a few copies of SolidWorks. To meet the needs of these customers SolidWorks acquired a small private company, Design Source Technology, that marketed a stripped down PDM package called PDMWorks. It was inexpensive and fit the needs of installations with perhaps two to five copies of CAD software. It did not use a relational database manager such as Oracle or Microsoft SQL but, rather, maintained model and drawing data using the basic file management capabilities of the Windows operating system.

**SolidWorks At Mid-Decade**

In early February 2005, SolidWorks held its annual user meeting in Orlando, Florida with over 2,200 attendees. One sign of the impact the company was having on the CAD market was the fact that 77 companies had booths in the meeting's exhibit area to show off SolidWorks compatible products. Also indicative of SolidWorks' marketing presence was the company's ability to have space pioneer Burt Rutan as the meeting's keynote speaker. He described how he had built SpaceShipOne, the first privately financed manned spacecraft, using SolidWorks software among other design tools.

By mid-2005 SolidWorks had installed about 190,000 commercial licenses of its software and was generating about $225 million in annual revenue. SolidWorks' revenue was over 21 percent of the parent company's overall revenue and, apparently, an even larger portion of the company's profits. Obviously, Dassault's acquisition of the company in 1997 was proving to have been a wise move on the part of the French company. Dassault has continued to maintain a hands-off approach to managing the SolidWorks subsidiary. There is virtually no joint marketing of the SolidWorks and CATIA products and, in fact, there is only limited software available from the company for exchanging data between the two systems.

The total installed base was closer to 400,000 seats due to the company's aggressive educational programs that provided schools with copies of SolidWorks at a steep discount. The company claims that over 700,000 students learn to use this software every year.

 

SolidWorks 3D Content Central has brought to reality a concept that many CAD pioneers dreamed about for years. Most products consist of some parts designed by the manufacturer and lots of parts procured from outside vendors. During design, dimensional data defining these external parts needs to be incorporated into the product model. Historically, this was a time-consuming manual task.

With 3D Content Central, parts suppliers are able to create SolidWorks compatible models of their components and post them on a web site managed by SolidWorks. Design engineers can download this data and incorporate the part information in the products they are designing. Nearly 100,000 parts were being downloaded per month in mid-2005 by SolidWorks users.

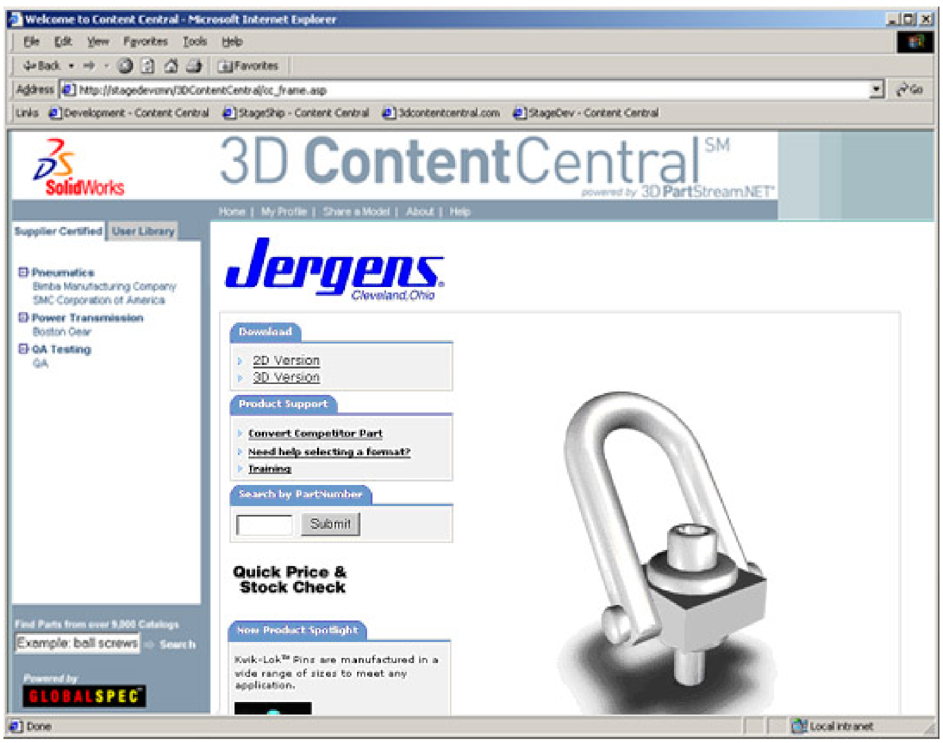


Figure 18.7
SolidWorks 3D Content Central

Another interesting development was the acceptance of eDrawing technology by non-SolidWorks users. Over 32,000 Pro/ENGINEER users had signed up to use this technology.

At this point, SolidWorks management consisted of:

- John McEleney – Chief Executive Officer
- Jeff Ray – Chief Operating Officer
- Joseph Esposito, Chief Financial Officer
- Chris Garcia, Vice President of Research & Development
- Bertrand Sicot, Vice President, North American Sales
- Dave Corcoran, Executive Vice President of Strategy

 

- Michel Gros, Executive Vice President, Europe
- Fuyuhiko Usui, President and CEO, SolidWorks Japan K.K.
- Ved Narayan, Vice President, Asia Pacific Operations
- Rainer Gawlick, Vice President, Worldwide Marketing
- Richard Welch, Vice President, Worldwide Customer Services

In July 2007, John McEleney announced plans to retire and Jeff Ray was appointed to replace him.

 

# Chapter 19

# Siemens PLM Software (Unigraphics)[1]

*Author's note: As discussed below, this organization has had a multitude of different names over the years. Many still refer to it simply as UGS and, although that name is no longer formally used, I have used it throughout this chapter.*

**McDonnell Douglas Automation**

In order to understand how today's Siemens PLM Software organization and the Unigraphics software evolved one has to go back to an organization in Saint Louis, Missouri called McAuto (McDonnell Automation Company), a subsidiary of the McDonnell Aircraft Corporation. The aircraft industry was one of the first users of computer systems for engineering design and analysis and McDonnell was very proactive in this endeavor starting in the late 1950s. Its first NC production part was manufactured in 1958 and computers were used to help layout aircraft the following year.

In 1960 McDonnell decided to utilize this experience and enter the computer services business. Its McAuto subsidiary was established that year with 258 employees and $7 million in computer hardware. Fifteen years later, McAuto had become one of the largest computer services organizations in the world with over 3,500 employees and a computer infrastructure worth over $170 million. It continued to grow for the next decade, reaching over $1 billion in revenue and 14,000 employees by 1985. Its largest single customer during of this period was the military aircraft design group of its own parent company.

A significant project during the 1960s and 1970s was the development of an in-house CAD/CAM system to support McDonnell engineering. Known as CADD (Computer Aided Design and Drafting), it was first implemented on an IBM 360/40 computer equipped with an IBM 2250 display terminal starting around 1966. In 1967, McDonnell Aircraft and Douglas Aircraft merged to form McDonnell Douglas Corporation (MDC)[2].

By 1976, the software had gone through 15 revisions and was running on IBM 370/168 mainframes using IBM 3250 displays. Tektronix 4014 and the company's own DGS (Distributed Graphics System) terminals were also utilized. The DGS consisted of either a Digital PDP 11/34 or PDP 11/70 computer interfaced to Evans & Sutherland Picture System II displays. Graphic manipulations such as pan and zoom were handled locally by the DGS while geometric construction was performed on the mainframe host computer. Remote DGS systems communicated with the host at a relatively slow 9600 bps. McDonnell Douglas at one time was using 80 DGS systems, 100 3250s and hundreds of 4014s.

Over the years, there were some limited attempts to market CADD to the general public. MDC's operating divisions were adamant that the software should not be sold to

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[1] UGS is one of the few companies in this industry that has an extensive history readily available. This data has been maintained on a web site, http://www.plmworld.org/museum, by John Baker, a long term employee of the company. Much of the early part of this chapter is based upon this material.

[2] McDonnell Douglas merged with Boeing in 1996.

 

any company that it perceived to be a direct competitor and as a consequence CADD, unlike Lockheed's CADAM, never really got off the ground as a commercial product. Among the few commercial customers were Timex and Cessna Aircraft. The latter was sold the software since its aircraft did not compete with anything produced by MDC. One competitor that did use the software was Northrup, but only because it was a partner with MDC on the F-18 program. The fact that the company wanted $250,000 for CADD software probably didn't help.[3]

Figure 19.1
Evans & Sutherland graphics System Running CADD

A major portion of McAuto's business consisted of providing commercial timesharing services, especially to engineering and manufacturing concerns. Typical of this activity was providing Finite Element Analysis (FEA) on a remote batch basis. McAuto was one of the first company's to offer the use of remote graphics terminals to prepare FEA models for analysis and to view the results graphically. The typical terminal used for this type of service was the Tektronix 4014 and the software was an internally developed package called FASTDRAW.

Clients could use FASTDRAW to build a model, submit it for analysis using programs such as ANSYS or MSC NASTRAN and then view the results. Eventually, this program was ported to Digital VAX computers and sold as an adjunct to Unigraphics. The president of McAuto in the early 1980s was Joe Quakenbush and John Clancy was the vice president in charge of the Unigraphics activity. In February 1983, Robert Fischer, the former president of National CSS, becomes president of McAuto replacing Quackenbush who retired due to health reasons. Clancy became vice president for Industry/Product Management.

**Unigraphics started with a company called United Computing**

United Computing was founded in 1963 by John Wright and several associates. Their first two-room office was above a hairdresser in Torrance, California. Within a few years the company moved a few miles away to Carson. The new facility had previously been a post office and occasionally people would come looking to buy stamps or mail a package.

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[3] Lavick, Jerry J., *Siggraph '76 Proceedings*, Pg. 279

 

United Computing's first product, introduced in 1969, was UNIAPT, a minicomputer based version of APT (Automatic Programmed Tool) as described in Chapter 3. APT was a part programming language used to compute tool paths that were subsequently post processed and punched onto a paper tape. The paper tape was then read into an NC machine tools where the program controlled the movement of the machine cutter, producing the part that was described using the APT language.

Figure 19.2
John Wright, Founder of United Computing

UNIAPT was one of the first NC programming systems sold directly to end users. Previously, most companies created their NC programs using time-sharing services provided by large providers such as McAuto and UCC (University Computing Corporation). The UNIAPT software followed basic APT principals fairly closely. APT commands were entered via a keyboard and there was no graphic feedback as we know it today. The system did have the ability to plot results, however. Moderately complex surfaces could be machined using an optional module called USURF.

Figure 19.3
DEC PDP-8 based UNIAPT System

United Computing was one of the first companies to license the ADAM software from Pat Hanratty's Manufacturing and Consulting Services (See Chapter 15). Supposedly this was a worldwide exclusive license except for Japan. Since Hanratty had his own way of defining “exclusive” it is not clear what restrictions the contract had on either party. Although the initial version of ADAM had been developed by MCS to run on the REDCOR RC-70 minicomputer with a Computek terminal, the code was intended to be machine independent. United Computing fairly quickly ported the software to a General Automation SPC-16 minicomputer and a Tektronix display. They also added a menu-driven user interface.

The software, UNI-GRAPHICS, was introduced in October 1973 at the Society of Manufacturing Engineers CAD/CAM II show at the Hilton Hotel in Detroit. These shows were the forerunners of what eventually became AUTOFACT. The software provided basic two-dimensional modeling and drafting capabilities. The company promoted this new software as a graphical front-end to UNIAPT. United had just six programmers working on the development of UNI-GRAPHICS at the time.

The typical configuration in addition to the SPC-16 minicomputer included either a Tektronix 4010 or 4014 terminal, an alphanumeric display for commands and messages, a 32-button program function keyboard, a tablet and stylus and a Tektronix 4631 hardcopy unit. Cursor control on the Tektronix terminal was typically with a pair of thumbwheel switches or joystick if the tablet was not used. A multi-user version of the software was introduced in August 1974 on the General Automation SPC-16/65 and the package was renamed Unigraphics without the hyphen.

United sold its first Unigraphics system to Los Alamos National Laboratory in New Mexico in September 1974 but the system’s installation was delayed until early 1975 while the company added support for Vector General graphics terminals and Xynetics flat-bed plotters. The first industrial installation was at an Alcoa facility in Lafayette, Indiana followed soon thereafter by another system at the U.S. Army depot in Corpus Christi, Texas.

In February 1975, the Unigraphics hardware was upgraded to the General Automation 1830 system and the graphic workstation was given the “Model 319” nomenclature. A typical configuration is shown in Figure 19.4.

Figure 19.4
Unigraphics Model 319 Terminal

In September 1975, United Computing introduced its first integrated NC product, Graphic Machining. Although MCS’ ADAM system had NC modules, they were problem plagued and United decided to develop its own software rather than try to fix the ADAM code. Eventually, this NC experience would become one of the company's technological backbones.

McDonnell Douglas acquired United Computing in April 1976. The company stayed in Carson and was operated as a McAuto subsidiary.

**Unigraphics Under McAuto**

Starting in 1976, McDonnell Douglas and the subsequent owners of Unigraphics continued to enhance this core software product and the vast suite of applications built on top of it. One of the first major enhancements was the addition of a user programming language, GRIP (GRaphics Interactive Programming language). Although the basic code for this capability was included in the ADAM software United licensed from MCS, it required considerable software effort to make it work effectively. Over the years, GRIP would be one of the key features along with its NC capabilities that distinguished Unigraphics from its competitors.

When McAuto acquired United Computing, one of the major problems was that Unigraphics ran on General Automation computers. These were not popular with most engineering organizations and McAuto began shipping a Data General Eclipse version in June 1976. The company had been delivering UNIAPT on smaller Data General Nova systems for some time as well as on Digital PDP-8s. Although Data General had a real-time operating system, RDOS, United developed its own operating system, TSS (Time Slicing System), which permitted multiple users to run independent sessions of Unigraphics. The company felt the need to do this since RDOS only allowed a single process to be running at any one time. The Data General version of Unigraphics was followed by a Digital PDP-11/70 implementation in early 1977.

The first Unigraphics user group meeting was held in December 1976 at United's Carson facility. Among the nine companies attending were ALCOA, Caterpillar, Harris Corporation and Los Alamos National Laboratory. The next year, at the August user meeting, there were 25 attendees and the meeting had to be moved to the local Douglas Aircraft plant.

In March, 1977, the company was successful in marketing Unigraphics internationally. Baker Perkins Ltd, of Peterbrough, England, a manufacturer of food processing equipment, purchased a four seat Unigraphics system. The software ran on a Data General S200 with 128KB of main memory, a 96MB removable disk drive, a 9-track magnetic tape backup system, a paper tape punch/reader and a Calcomp 960 plotter. The complete system including the Unigraphics software sold for over $400,000. The S200 computer required an air conditioned room for the CPU and disk drive and the Tektronix terminals required controlled lighting for the users.

In April 1978, the company launched Unigraphics version R1 where the "R" stood for "Restructured." The new software supported 256 data layers and chain selection of graphical entities. R2 followed in July 1978 and R3 just three months later. R4 was released in March 1979. The latter was mostly a bug fix. At this time, it was not possible to simply patch an existing release. To fix bugs, a software company had to ship a complete copy of the software. It was an awkward way to fix minor bugs.

About the same time, McAuto made some significant changes in the management of what was still being run as United Computing. The original United Computing operation was shut down and the Unigraphics product line became part of a newly formed CAD/CAM Division of McAuto. This division included other design related activities such as CADD, Fastdraw and some DNC software. John Wright and other early United employees who were still around left the company and George Meister, an early CAD pioneer employed by MDC's Douglas Aircraft Division took over the Unigraphics operation. Meister had actually worked with Pat Hanratty at Douglas Aircraft developing software for designing wiring harnesses for commercial aircraft.

The first release under the new McAuto management was called D1. The "D" stood for double-precision math. In February 1980, the Unigraphics development operation moved to a new facility in Cypress, California. At the time, it was surrounded by strawberry fields most of are long since gone.[4]

By 1980, McAuto had revenues of over $400 million, 5,500 employees and was supporting over 20,000 remote terminals and nearly 300 computers. Of the company's revenue, $46 million involved CAD/CAM systems. While this would have made it one of the leading companies at the time in terms of revenue, the fact that over 70 percent of this revenue was generated by internal aircraft divisions resulted in little external awareness of what the company was trying to sell.

The Unigraphics User Group started to become more important around this time. They began publishing a newsletter called "Interact" in August 1980 with Dave Berry of Harris Corporation as the editor. At that time the user group's officers were Tom Meagher of Caterpillar as chairman, Don Leake of Harris as vice-chairman and Christ Tayon of Valeron as secretary/treasurer.

Unigraphics development under the new McAuto management picked up momentum during 1980. In September, Version D2 was released with a view-independent coordinate system as well as new NC and geometry editing modules including the ability to create and edit sculptured surfaces. This version also saw the introduction of a finite element modeling module called GFEM. From this point forward, Unigraphics was an effective three-dimensional design and manufacturing system.[5] A maintenance release, D2.1 came out in February 1981 with support for the Digital VAX computer. The company announced that it would also support Data General 32-bit systems. The next release, D3.0, in April 1982, was the first Unigraphics software that supported raster displays and color (up to seven different colors).

In October 1981, John Clancy was promoted to vice president of McAuto with responsibility for all the company's CAD/CAM activity. One result was that McAuto's St. Louis headquarters became the worldwide headquarters for Unigraphics. George Miester continued to run the Unigraphics development and support operation in Cypress, reporting to Clancy. By this time, the company had installed about 100 systems external to MDC.

Unigraphics was strong in NC since that was the area where United Computing had started and the company claimed to have over 1,000 postprocessors available. According to the November 1981 issue of *CAD/CIM Alert*:

> "UNIGRAPHICS qualifies as a genuine 'sleeper' – a fine product that for some reason, is not well known – in spite of the fact that the

[4] www.plmworld.org/museum/the_80s.htm
[5] www.plmworld.org/museum/the_80s.htm

MCAUTO UNIGRAPHICS convention booth is one of the most dramatic. At NCGA '81 and elsewhere, MCAUTO installs a DNC mill alongside its CAD/CAM system and actually machines the parts created on the graphics system before your very eyes!..... We rate UNIGRAPHICS 'excellent' in user-friendliness, 'excellent' in 3D mechanical design, 'poor' in schematic drafting, and 'sorely lacking' in market identity. This system deserves serious consideration by anyone looking for a CAD/CAM system for 3D mechanical design and drafting."[6]

**Low cost systems**

In the early 1980s there was a great deal of interest among CAD/CAM system vendors to develop lower cost systems, especially for situations where a customer wanted to purchase just one or two seats. Since most early systems were built around a minicomputer core that was designed to support as many as a dozen terminals, the entry level cost for a single seat configuration was often $200,000 or more, especially if the minicomputer was something like a VAX 11/780. McAuto's initial attempt to provide a lower cost alternative was the ADS-100 (Autonomous Design Station) which started at $100,000 (the equivalent to about $200,000 today).

The ADS-100 was a fully functional stand-alone system consisting of a Data General S140 computer, a 25MB disk memory, an 8-inch 1.2MB floppy disk, a Megatek raster display, an alphanumeric display and a single user Unigraphics software license. A storage tube display version of the ADS-100 was also available. As shown in Figure 19.5, the system even included the furniture. The hard disk was used to store the operating system and Unigraphics software while design files were stored on the floppy disk.


Figure 19.5
Low-Cost ADS-100 System (plotter and paper tape reader/punch were optional)

[6] *CAD/CIM Alert*, November 1981, Pg. 7

 

A variation of the ADS-100 without the computer portion was marketed as the DDS-100 (Dependent Design Station). These single user systems were designed to be connected to a central CPU. This unit was later called simply the D-100.

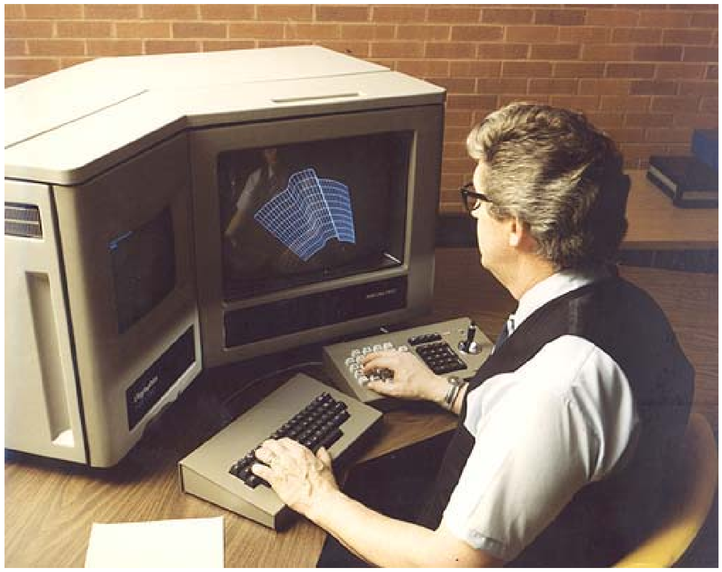

Figure 19.6
D-100 terminal showing keyboard and program function keyboard (PFK)[7]

**Unigraphics II**

In mid-1982, Unigraphics was basically still the original MCS ADAM software although significantly revised by United Computing and subsequently by McAuto. The development manager at this time was Tom Rafferty who would join Auto-trol Technology a few years later as head of its ill-fated Mosaic project. Rafferty convened a meeting of senior technical managers on the Queen Mary in Long Beach harbor to discuss the need for a major overhaul of Unigraphics. Additional meetings over the next month resulted in the launching of a major development project that eventually resulted in a substantially new product subsequently called Unigraphics II. Internally, this group was referred to as "Snow White and the Seven Dwarves". In addition to Rafferty, the group consisted of

- George Allen
- Chuck Grindstaff
- Vic Hambridge
- Chris Mehling
- Gary Newell
- Paul Sicking
- Wil Valenzuela

John Baker points out on his web site that all of the "Dwarves", with the exception of Gary Newell who passed away in the spring of 2000, are still with the

[7] http://www.plmworld.org/museum/hall/Hall_Workstations.htm

Unigraphics organization.[8] In fact, as of mid-2007, Chuck Grindstaff was the executive vice president responsible for all UGS product development and marketing.

While work got underway on Unigraphics II, the company continued to release new versions of the existing Unigraphics product. September 1982 saw the announcement of Version D4.0 with an implementation of GRIP extended to work with NC applications, IGES support, and three-dimensional mass properties. This software began shipping in February 1983. Version D4.1 was released in mid-1983. It took full advantage of 32-bit architecture based on work being done for Unigraphics II. The full use of the 32-bit capabilities on Digital and Data General computers resulted in significant performance improvements. This was the last release of the original Unigraphics that contained any significant enhancements. While there were Releases D5.0 and D6.0, they were mainly maintenance releases, particularly for user of older 16-bit computer systems.[9]

In August 1983, McAuto announced Unigraphics II Version 1.0. The earlier software was now called Unigraphics I. The new software entailed a virtually complete re-architecting of the part data model including adding associative relationships. In addition, there were a large number of enhancements and new approaches to creating models and making drawings including:

- Unigraphics File Management (UGFM) system
- New view and layout capabilities to support drafting
- Perspective views
- View dependent editing
- General part merge as a replacement for patterns
- User defined attributes
- Major improvements in drafting functionality
- Dual dimensioning
- Associative dimensions, labels and other annotation
- Grouping of objects
- Major enhancements in CAM and GFEM
- First support for sheet metal operations
- Improved tools for writing user macros.
- User-definable drafting standards.
- The ability to machine multiple surfaces.
- FORTRAN-based post-processors..
- Better access to the Unigraphics database for user applications.

Unigraphics II was implemented on 32-bit Digital VAX and Data General MV systems. While there was limited support for the older Tektronix display hardware, it was obvious that these devices were being phased out as supported terminals. Actual shipment of non-beta software to customers did not occur until early 1984. The Unigraphics II software could read older Unigraphics data but going the other way meant that associativity information would be lost.

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[8] http://www.plmworld.org/museum/the_80s.htm
[9] Ibid

Major shortcomings of Unigraphics II were the lack of hidden line removal and the ability to produce shaded images.[10] Unigraphics II was generally well received in the marketplace. As an example, Continental Can placed a $3.5 million order for a 40 workstation system later in 1984.[11]

**Unigraphics terminals and platform support**

In the early 1980s, Unigraphics was supported on both 16-bit and 32-bit computers from Digital and Data General. The terminals were Tektronix 4014s with a 5" alphanumeric display typically mounted on top of the 4014 and a 32-button function keyboard. These were connected to the host computer via a 9600 bps (bits per second) link, whether it was connected locally or remotely. Unigraphics did not take advantage of the 4014's limited refresh capability, using the small alphanumeric display for menus and messages. During the period, when Unigraphics systems were minicomputer based, the software was sold on a "per system" basis. Therefore, the cost "per seat" came down significantly as additional terminals were installed.

At AUTOFACT III in Chicago in November 1981, McAuto demonstrated a new Unigraphics user interface and a new system configuration that consisted of a Data General Eclipse C-130 computer, a Megatek color raster display and a 12-inch alphanumeric display priced at somewhat less than $100,000.[12] One problem with all McAuto terminals described in this section is that they were interfaced to the central computer over a standard 9600 bps serial interface. This frequently had a negative impact on performance. The one exception was the D-135 that increased this speed to 19,600 bps.

In the mid-1980s, McDonnell Douglas' primary platform for Unigraphics was minicomputers from Data General and Digital incorporating graphic terminal that used display technology purchased from Megatek but assembled by McDonnell Douglas. At the 7th Annual Unigraphics User Meeting in February 1983, Data General announced the MV1000, the most powerful computer that supported Unigraphics at the time. It could be equipped with up to 18GB of disk storage and 16MB of main memory. McAuto estimated that a fully configured MV10000 could support 12 to 14 Unigraphics terminals.[13]

In mid-1983 McAuto introduced a low-cost monochromatic raster workstation called the D-90 which could be used with either Data General or Digital computers. It sold for $17,500[14]. It was basically intended to replace terminals that used Tektronix storage tube displays.

The company also launched a new low-end system built around a 32-bit Data General MV-4000 computer. Called the M-150, it was priced at $98,000 with one workstation and $115,000 with two. Unlike the earlier ADS-100, the M-150 could handle advanced software such as solids modeling and machining multiple surfaces.[15]

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[10] *Computer Aided Design Report*, April 1984, Pg. 7
[11] *Anderson Report*, December 1984, Pg. 2
[12] *CAD/CIM Alert*, November 1981, Pg. 6
[13] http://www.plmworld.org/museum/the_80s.htm
[14] *Anderson Report*, August 1983, Pg. 3
[15] *Computer Aided Design Report*, August 1983, Pg. 11

 

McAuto was totally agnostic as far as which graphics vendors it worked with. In late 1983 it signed a contract with Evans & Sutherland for PS 330 displays and then in late 1984 introduced a new workstation, the D-2300, based on Megatek's Merlin 9200 with 3,072 by 2,304 resolution. This unit supported real time pan, zoom and rotation of both wireframe and shaded images.[16] It would be nearly a year before any D2300s were delivered. They were overly expensive at more than $60,000 per unit (this did not include the CPU or any software) and somewhat unreliable.

In May 1984, McAuto introduced two new design stations, the D-120C and D-120CE models. The C obviously stood for color. There were also M (monochromatic) versions of these raster terminals that had the same capabilities as the color systems. According to the UGS history web site:

> "The two new units were basically upgraded D-100's and were the last design stations sold that were packaged as free-standing furniture. The "E" models had extended graphics capabilities that supported local hardware dynamic rotation of wire frame images as well as support for panning and continuous zooming using the joystick controls. While these stations could still be used with Unigraphics I, many of the enhanced capabilities such as increased graphics memory, the local dynamics, gray scale control of the background, etc. were only supported with Unigraphics II.
>
> The D-120C systems had a list price of $48,000 and the D-120CE systems were sold for $53,000. Note that these systems could also have optional shader hardware added which allowed users to display shaded images of UniSolids models. These were static images and users had to perform a software rendering of a model and then the image would be automatically displayed with what was really a second graphics driver hooked to a common display screen. This was also the only way to create hidden-line images from a UniSolids model. Up until then, users had to purchase a special second terminal that was only used to show shaded images and they had to manually switch the input before they started the rendering operation."[17]

A new terminal, the D-125, was introduced in early 1985. It was a modular unit along the lines of the D-90 with plastic cases for the keyboard and PFK. No monochrome version of the D-125 was offered as the company moved to only support color displays. A basic D-125 sold for $43,000 while a D-125CE with extended graphics capabilities had a list price of $48,000. This was followed by the D-135 in mid-1986. In addition to a 19,600 bps interface, this terminal incorporated a 1MB graphics memory enabling it to handle more complex images than D-125 machines that had only 192KB. The D-135 was the last significant terminal to carry the Unigraphics label.[18]

During the later part of the 1980s, the company reduced its dependency on specially configured hardware systems and began to support industry-standard UNIX

[16] *CAD/CIM Alert*, October 1984, Pg. 3
[17] http://www.plmworld.org/museum/the_80s.htm
[18] Ibid

workstations as described below. By 1990, the company supported a variety of workstations from Digital, Hewlett-Packard, and Sun Microsystems.

**McDonnell Douglas and the AEC market**

McAuto had long been involved in providing timesharing services to civil engineering users. It was one of the first organizations to provide MIT's ICES software on a time-sharing basis as described in Chapter 5. Within McAuto, the AEC activity was known as the EDAC division for Engineers, Designers, Architects and Constructors. Initially, little AEC software was developed internally by McAuto, especially none for the architectural market. Meanwhile, Applied Research of Cambridge England, which was founded in 1969, was developing two packages for use by architects, Building Design System (BDS) and Graphic Data Systems (GDS). In March 1981, McAuto signed an exclusive license agreement with Applied Research to market GDS and BDS. A few years later, in mid-1985, McAuto acquired the company outright along with its software for $12.5 million.

GDS was a fairly straightforward drafting package particularly applicable to architectural and engineering drawings. BDS was implemented to facilitate the design of repetitive buildings such as schools and hospitals. It could not handle sloped roofs, curved walls or walls that met at anything other than a right angle. BDS was a conceptual design and modeling package. In order to produce working drawings, data had to be transferred to GDS. On the other hand, there was no link for transferring GDS data to BDS.

Initially, the software ran on Prime computers using Tektronix 4014 graphic display terminals. In the 1981 time frame, the software was quite expensive. According to *A-E-C Automation* Newsletter, GDS software ranged from $73,000 for two seats on a Prime 150 to $140,000 on a Prime 550-2. BDS software on the same systems was $150,000 to $287,000. This was just for the software, it did not include any of the hardware.[19] Prices were reduced substantially over the next several years. By 1983 an entry-level GDS system including a Prime 2250 computer and a Tektronix 4114 terminal sold for just $100,000 while the BDS software was an additional $38,000. A four-station system was $191,200.[20] One strategic issue the company never fully resolved was that the AEC products were predominately offered on Prime computers although a Digital version was available by 1983, while Unigraphics was available for Digital and Data General systems. The company was also slow in offering existing time-sharing software on the Prime platform. As an example, by 1985 COGO had been ported from time-sharing systems to Digital minicomputers but not to Prime computers which were used by the majority of GDS and BDS customers.

A new AEC division was established in early 1984 under Bill Vickroy. The company scored its first big coup when HNTB (formerly Howard, Needles, Tammen & Bergendoff) , a major engineering firm, decided to install VAX-based GDS systems in 33 offices.[21] A few months later, the company announced that GDS would also be available on the Digital Micro-VAX.[22]

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[19] *A-E-C Automation Newsletter*, May 1981, Pg. 3
[20] *A-E-C Automation Newsletter*, April 19831, Pg. 1
[21] *Anderson Report*, January 1984, Pg. 2
[22] *CAD/CIM Alert*, August 1984, Pg. 6

 

In mid-1985 McAuto signed an agreement with Moss Systems of Horsham, England to market that company's topographic modeling and highway design software package also called MOSS. At about the same time, Auto-trol Technology also signed a distribution agreement with Moss Systems.

**IBM as both competitor and partner**

Although IBM competed with McAuto in the overall CAD market, that did not stop the company from signing McAuto as a reseller of IBM 4361 computers. On December 5, 1984 McAuto announced that it would port Unigraphics II software to the IBM platform. A system consisting of a 4361 Group 5 processor with a 30MB disk drive, four 5080 terminals, Unigraphics II software including NC functionality and an IBM 7375 plotter (same device as the HP 7585) was to sell for $600,000. McAuto planned to sell just turnkey systems and announced that it would not sell unbundled software for the 4361.

Although initial plans were to utilize only a limited amount of the 5080's local graphics capability, the company did use the main display rather than a separate alphanumeric display for menus. McAuto announced that by the end of 1985 it would offload many graphics functions to the 5080. This version of Unigraphics never gained much traction in that IBM's sales force was not particularly interested in bringing a software vendor into a customer when that software vendor also sold other computer platforms.

McAuto sold 11 Unigraphics systems utilizing the 4361 before the agreement with IBM dissolved. Eventually 10 of the 11 converted to either Digital or Data General computers and remained Unigraphics users.[23]

**The name games start**

The company covered in this chapter has had more different names during the past 25 years than any other company in the industry. In early 1985 McDonnell Douglas dropped the McAuto name and created several specialized companies, each with its own name and identity. These were McDonnell Douglas Aerospace and McDonnell Douglas Information Systems.

As part of the latter organization, the CAD operation was called CIMTECH which stood for Computer Integrated Manufacturing Technologies Company. That did not last very long and in April 1985 CIMTECH was renamed McDonnell Douglas Manufacturing Industry Systems Company or MISCO. A few months later John Clancy became president of McDonnell Douglas Information Systems Group, the new name for McAuto. George Meister relocated to St. Louis and became vice president and general manager of the MISCO.

Other key individuals at this point in time on the mechanical side of the company were:

- Art Francis – vice president, marketing
- Guy Rose – vice president, sales
- Phil Crater – vice president, operations
- Tom Rafferty – director, research and development

[23] Interview with John Baker on July 18, 2006

 

The counterparts in the AEC group were:

- Gary Alexander – senior vice president and general manager
- David Lonsdale – vice president, engineering services marketing
- Ray Pittman – director, engineering services
- John Purcelli – vice president, operations
- John Valentino – vice president, national sales
- John Emerson, manager, AEC development

The AEC part of the company was not immune from the name game. In May 1988, the Architectural, Engineering and Construction Systems Company as it was then known, changed to the Built Environment Group.[24] This was later changed to Built Environment Technologies. Both groups were part of McDonnell Douglas' Systems Integration Company.[25]

The name was changed once again in early 1987 to McDonnell Douglas Manufacturing and Engineering Systems Company with Clancy as its president. It was usually referred to subsequently simply as M&E.

**UniSolids and Parasolid**

UniSolids was developed by McDonnell Douglas in early 1982 based on PADL (Part and Assembly Description Language) from the University of Rochester. PADL-1 was a CSG (Constructive Solid Geometry) modeler that created solid models by combining and subtracting solid primitives. The 1982 demonstration version of this software simply handled blocks and cylinders that were oriented along the X, Y or Z axis. It was never sold but it did prove that the concept was viable.

The solids modeling software was first shown publicly at the 1982 AUTOFACT conference in Philadelphia. The McAuto staff put together a very impressive demonstration of UniSolids. According to Baker:

> "…a model of the Liberty Bell was designed with UniSolids, passed to Unigraphics where a tool path was created using GRIP NC, post processed and then transferred to a 3-axis milling machine via McAuto's DNC system. There a robot (programmed with the Place software) placed blocks of foam board into an automatic fixture on the milling machine where they were machined with the shape of the Liberty Bell (including the crack) and then the robot removed the finished blocks and inserted them in a box, closed the cover and delivered the completed package to the McAuto presenter where he presented it to someone in the large crowd of people watching the demonstration, which was repeated once every hour."[26]

Version 1.0 of UniSolids, based on PADL-2, was delivered to customers starting in May 1983. This initial version of UniSolids was a stand-alone program that initially was not very tightly integrated with Unigraphics. As an example UniSolids did not support some of the advanced surface definitions contained within Unigraphics. It was

[24] *Computer Aided Design Report*, June 1988, Pg. 16
[25] *Computer Aided Design Report*, October 1990, Pg. 2
[26] http://www.plmworld.org/museum/the_80s.htm

 

difficult to produce drawings from UniSolids models and it was equally difficult to incorporate two-dimensional Unigraphics shapes into UniSolids models. UniSolids sold for $50,000 and was available initially only on the Digital VAX system. Version 1.1 with improved performance also provided support for Data General MV systems when it was released in September 1983. This was followed by Version 2.0 in November 1984 which enabled a user to import Unigraphics profiles and use them to extrude solid models.

In 1988, McDonnell Douglas acquired Shape Data from Salt Lake City-based Evans & Sutherland. E&S was primarily a hardware manufacturer and its major market was flight simulation. Hence, it never made much sense as to why the company acquired Shape Data whose main product was a solids modeler released in 1975 called Romulus. Shape Data's most recent software at the time of this acquisition was a boundary representation or B-rep solid modeler called Parasolid that was not an end user package but rather component software that other software firms could use in their products.

For the next several years Shape Data's resources were directed at adding Parasolid technology to Unigraphics. This they did quite well. Unigraphics Version 7.0 released in December 1989 included Parasolid as an option called UG Solids. It differed from Unisolids in that it was tightly integrated with the Unigraphics data structure much like the company's surface modeling technology.

Unlike competitive system and the earlier Unisolids package, no translation of data from surface definitions to solids or the other way was required. Graphical manipulation of solids models was no different than the manipulation of wireframe models. The transition from wireframe and surface design to solids design was perhaps the best in the industry at the time. Operators doing drafting or NC programming did not need a UG Solids license unless they were going to make changes to the model.

**Jumping on the PC CAD bandwagon**

In October 1985 McDonnell Douglas announced a new organization, the PC Productivity Systems (PCPS) division, with plans to create a PC version of Unigraphics I with price of $2,000. It didn't happen quite that way. The company's first PC package was a product called Crossroads which was introduced at the 1986 NCGA conference. Crossroads was a blend of new software, code ported over from Unigraphics and licensed software. Basic geometry functions were taken from Unigraphics while the graphical user interface used the GEM DESKTOP from Digital Research. The software ran on IBM PC/XT and PC/AT computers that required additional memory, a floating-point co-processor, a graphics card and a 20MB hard disk.

Crossroads was a three-dimensional graphics package with a variety of surface types including ruled and spline surfaces. In its initial implementation, these surfaces could only be used to calculate mass properties. No NC software was available for machining the parts designed with Crossroads. Further restricting the marketability of this package was the fact that no translator between Crossroads and Unigraphics was immediately available. From a user interface point of view, it looked surprisingly similar to current PC-based systems as shown in Figure 19.7.

 

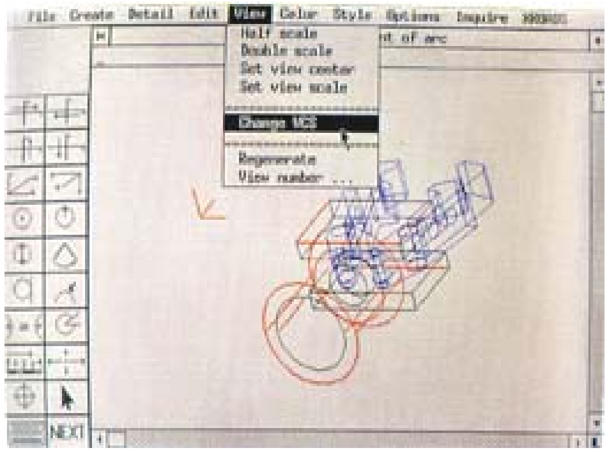


Figure 19.7
PC Productivity Systems Crossroads User Interface

McDonnell Douglas planned to market and sell Crossroads through the new PCPS organization. Actual sales were handled by a dealer network rather than the company's own sales force with the initial list price set at $2,995. Shipments of this product began in August 1986, about five months later than originally planned. By the end of the year the company had sold just 250 copies worth perhaps $750,000 at retail. Probably as a result of the products poor sales, the company consolidated the PC Productivity Systems group with its other mechanical and AEC CAD operations. The plan was to continue selling Crossroads through a dealer channel but by June 1987 McDonnell Douglas was cutting the product's advertising budget.[27]

*Computer Aided Design Report* reported in its June 1987 issue on an extensive evaluation of mechanical PC CAD software the publication had performed. Crossroads did not fare very well, rated behind MCS' Anvil 1000, AutoCAD and Computervision's MicroDraft but ahead of Intergraph's MicroStation.

> "Crossroads strikes us as a poorly conceived product. Few engineers can make effective use of three-dimensional models in PC-based systems. Three-D is used for design studies, assembly modeling, N/C programming, and finite element analysis. Yet Crossroads to date offers none of those capabilities…… After working with the product, it's clear why it is selling poorly…. Crossroads may get a second chance if it can be integrated with McDonnell Douglas's (sic) Unigraphics II in a sensible way. As a satellite to more powerful systems, it could still have a mission."[28]

In a mid-year report, Daratech did not include Crossroads as one of the ten top selling PC CAD packages – it simply lumped it in with "other."[29] McDonnell

[27] *Computer Aided Design Report*, March 1987, Pg. 11
[28] *Computer Aided Design Report*, June 1987, Pg. 1
[29] *Computer Aided Design Report*, October 1987, Pg. 15

 

Douglas threw in the sponge on Crossroads in February 1988 due to poor sales. In retrospect, the problem with the Crossroads product was the fact that PCs of that era simply did not have sufficient processing power to adequately handle the complexity of the software package's three-dimensional capabilities. By the time a user added memory and other performance enhancing features to a PC the cost was probably not much less than some of the low-end UNIX workstations.

**Unigraphics II matures**

For the first year and a half after its launch, customers were slow to make the transition from Unigraphics I to Unigraphics II. This switch picked up momentum in March 1985 when the company began shipping Unigraphics II Version 2.0 with improved performance and reliability. Version 2.0 also included a mechanisms module, improved NC capabilities and improved procedures for defining default operations. The last full release of Unigraphics I, Version D6.0, was shipped to customers in August 1985.

The Unigraphics business unit seemed to shift into a higher gear in 1985 after doing about $104 million in revenue in 1984. The software was available on Digital's new high-end VAX 8600 systems and for the first time, unbundled software was being sold. Varco-Pruden, a manufacturer of metal buildings, closed a $3.3 million deal for software only. By mid-1985 there were 377 companies using Unigraphics systems, about half running Unigraphics I and the other half using Unigraphics II. About 57 percent were using Digital computers while the rest were Data General systems.

Version 3.0 was released in November, 1985. It contained enhanced visualization capabilities including a new package, UniPIX, based on Brigham Young University's BYU-Movie software. This program created high quality images of Unigraphics models. MISCO, as the company was then known, also began shipping GRIP programs submitted by users. It was referred to as the GRIP International Library. Initially, the library was distributed on magnetic tape to customers upon request. Later it was put on CD-ROM and distributed with the Unigraphics software.

The 10$^{th}$ Annual Unigraphics User Meeting was held in Long Beach, California in February 1986. While the previous user meeting had dwelled on problems associated with making the transition from Unigraphics I to Unigraphics II, this meeting was focused on the newer software packages. MISCO also used this meeting to announce that UniAPT would no longer be supported and that maintenance fees were being suspended. In reality, the technical personnel in Cypress who had UniAPT expertise continued to help users on an informal basis, probably until 1995.[30]

In March 1986, the company announced Unigraphics II ACCESS-50 which enabled users to access Unigraphics software on a central computer from a PC. ACCESS-50 used the same GEM DESKTOP from Digital Research that was being used by the PC Productivity group. Unigraphics II Version 3.2 marked an important transition for the company. It incorporated support for the Digital VAXstation II/GPX, the first commercial workstation-class product this software ran on.

By the fall of 1986 Unigraphics II was being upgraded at a fairly rapid pace. Automatic finite element mesh generation software had been added as well as complex surface trimming and more comprehensive assembly design. Perhaps the most significant

[30] http://www.plmworld.org/museum/the_80s.htm

technical development in late 1987 was the introduction of Unigraphics software that would update NC tool paths when the underlying geometry changed.[31]

The company announced in January 1987 that it would no longer sell Data General hardware although it would continue to sell unbundled software for DG machines for a limited time, probably not past the end of 1988. This raised such a storm of protest at the user meeting in February that the company agreed to provide enhancement releases for five years and full maintenance and support for six years.[32]

**Major changes in product and management**

At the user meeting that year, the company announced a major change in how software would be priced in the future. Until this point, the company had sold software on a per system basis with different prices for small and large machines. Customers could run as many terminals off each system as the computer could physically handle and at a performance level the users were comfortable with. The new approach priced software and maintenance on a "per seat" basis. A license management program, Access Control, managed the number of users authorized to use each software module.

The company was fairly liberal in helping customers make this transition. Some were able to reduce maintenance charges while others simply "banked" unused licenses until they were needed. Phasing in the new license management strategy started with the Design/Drafting module in Release 4.1 in March, 1987. Release 4.1 also included support for Digital's VAXstation 2000.[33]

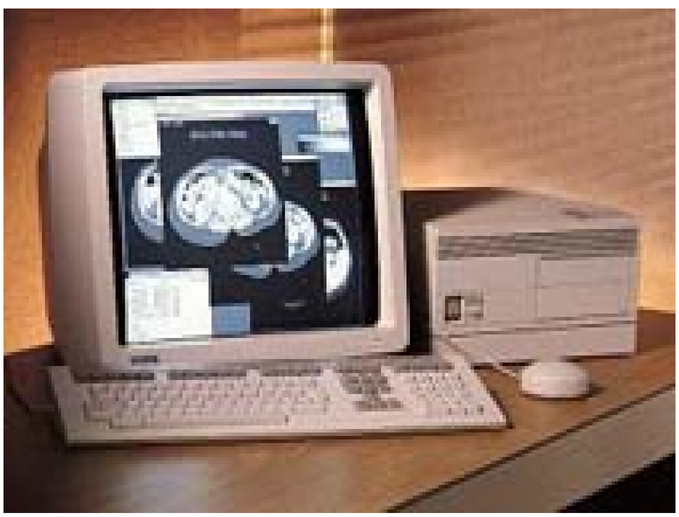

Figure 19.8
Unigraphics II Running on VAXstation 2000

In October 1987, Clancy resigned as president of the company's CAD operation and subsequently became president of Valisys, a vendor of NC quality assurance software.[34] John Mazzola was appointed executive vice president of the Manufacturing

[31] *Anderson Report*, November 1987, Pg. 7
[32] http://www.plmworld.org/museum/the_80s.htm
[33] Ibid
[34] *Anderson Report*, November 1987, Pg. 2

 

and Engineering Systems Company, reporting to Jeremy Causley, group executive vice president of McDonnell Douglas Information Systems Group.[35]

Unigraphics II Version 6.0 was released in December 1988. It incorporated advanced hidden line removal, NURBS curves, curvature analysis and a new program, UG Detail Drafting. The latter program was a lower cost version of Unigraphics intended to support users simply interested in producing engineering drawings. It incorporated pre-programmed macro commands and GRIP programs that facilitated this type of work. The user interface included a large tablet menu with nearly 400 commands laid out on it. This package was in the company product line until Version 10.0 was released several years later.

Version 7.0 was released in December 1989. It included UG/Solids, based on the recently acquired Shape Data Parasolid modeler. UG/Solids was much more tightly integrated with Unigraphics than the company's previous solids modeler technology. Solid models could be machined using standard Unigraphics NC software. This was an extra cost module which was provided as a no-cost upgrade to existing UniSolid customers. It did not however, support parametric definitions. That would have to wait for V 10.0.

Figure 19.9
John Mazzola

By 1990, the use of dimension-driven modeling software was becoming the technology of the future. PTC and SDRC were making waves with Pro/ENGINEER and I-DEAS. McDonnell Douglas' response to these competitive products was a Parasolid-based package called UG Concept that was released with Version 8.0 in March 1991. It enabled a user to create solid models that could be modified by simply changing dimensions. Geometry could be unconstrained, constrained or over constrained. The software used color codes and symbols to illustrate these conditions. Sketches defined in two dimensions could be used to create extruded solid shapes.

Once a model was created in UG Concept it could be transfered to Unigraphics where it could be further refined although Unigraphics could not make changes by simply

35 http://www.plmworld.org/museum/the_80s.htm

modifying dimensions. UG Concept also used a simplified menu structure that was the start of a new user interface for the Unigraphics suite of software.[36]

**General Motors and EDS change the future of Unigraphics**

On June 27, 1984 GM agreed to buy Electronic Data Systems (EDS) for $2.5 billion. On October 18, 1984 the merger was finalized, and EDS became a wholly owned subsidiary of GM. As a result of this acquisition, virtually all of GM's data processing activity including a large number of individuals and a substantial amount of computer hardware was transferred to the EDS subsidiary. In addition, EDS hired many new people to the point that it caused a housing boom in the Detroit suburbs.

A huge data center was established in Auburn Hills, Michigan to support GM's data processing requirements as well as those of other clients. Within a few months, EDS as it was still known, began to take charge of GM's computer efforts in engineering design and analysis. By late 1986 it was apparent to EDS that the smorgasbord of systems being used throughout GM for engineering design had to be rationalized. EDS then set out to select one or more "preferred providers."

Probably no business development had a greater impact on Unigraphics than its selection by General Motors in November 1987 as that company's primary supplier of CAD technology. GM began looking at how computer graphics could improve automotive design in the early 1960s (see Chapter 3). As CAD systems matured the company implemented a combination of purchased turnkey systems from numerous vendors including Computervision, Applicon, Calma and Auto-trol as well internally developed software. The latter category included a package called the Corporate Graphic System which was used by many GM division for body design. By 1987, numerous GM organizations were also implementing PC based CAD systems, particularly AutoCAD. Unigraphics was not one of the systems installed at GM at this point in time except for some robotic programming software.

GM called the consolidated system they were looking for C4 for CAD, CAE, CAM and CIM. GM's evaluation process was extremely thorough, comparable in many respects to large federal government procurements at the time. As part of the evaluation, vendors were required to perform a Live Test and Demonstration that exercised virtually every software module sold by each company.

As anyone who has worked with EDS at that time knows, the company had a huge corporate ego. They believed that since GM was the largest industrial company in the world, it could dictate standards in areas such as CAD technology. The plan was that EDS would work with the selected software vendors to establish these standards. According to *Computer Aided Design Report* the standards would encompass:

- "Geometric representations – the math used to describe car designs
- display drivers – the way CAD/CAM programs communicate with graphics terminals and work station display adapters
- user controls – the ways humans communicate with CAD/CAM applications
- communications between CAD/CAM systems and between CAD/CAM and non-graphic data bases

[36] *Computer Aided Design Report*, October 1990, Pg. 2

 

- hardware independence – so that applications can run on many brands of computers"[37]

These were all good objectives although most companies that were not selected as preferred suppliers would object to not having a say in their development. The plan was to take three years to develop the standards and then publish them for other vendors to adopt. It sounded good on paper but not terribly practical.

By the end of 1987, EDS had narrowed the selection process down to CADAM and Unigraphics and ended up choosing both. Interestingly, EDS dealt directly with CADAM, Inc. in this selection process, not with IBM. In spite of this, CADAM was not used extensively by GM and Unigraphics clearly became the preferred software package.

One result of EDS' selection was the increased need to support Unigraphics on UNIX workstations from Apollo, Sun and Hewlett-Packard. The Apollo version was demonstrated at the March 1988 National Design Engineering Show in Chicago. In mid-1988 the company signed a $15 million OEM deal with Apollo shortly after they had signed a $20 million deal with HP.[38] About this same time, the company added NURBS (Non-Uniform Rational B-Spline) surfaces to Unigraphics, eventually replacing the older parametric-cubic surfaces. In spite of being shut out of the GM deal, Digital continued to be a big user of Unigraphics software. By April 1988, it had installed 500 Unigraphics systems around the world.[39]

**Unigraphics becomes an EDS division**

The EDS subsidiary of GM acquired McDonnell Douglas Systems Integration Co. on November 4,1991 for $350 to 400 million. Over 2,000 MDSI employees became EDS employees with this transaction. The Unigraphics activity became the EDS Unigraphics Division and most of the former MDSI managers led by John Mazzola stayed with the new organization. Mazzola, as president, reported to Hank Johnson, the head of EDS' Manufacturing and Distribution Services business unit.

Johnson was no stranger to the CAD industry having managed the marketing of GM's Corporate Graphic System for EDS. With the acquisition, this EDS operation also took over the development and marketing of Parasolid. The Graphic Data System (GDS) activity, on the other hand, ended up in another EDS division also reporting to Johnson.

At the time of the acquisition, EDS was a 70,000 person, $7 billion computer services company with about 40 percent of its business coming from parent GM.[40] In June 1992, EDS Unigraphics moved into a new headquarters building in Cypress, California. Version 9.0 of Unigraphics II was released in August, 1992 followed by 9.1 in December. The company ended up supporting this software release with many patches for several years due to the lengthy rollout of Version 10.0. It was the last version to use the Unigraphics II nomenclature.

**Product data management**

The company's first PDM product was Infomanager which enabled users to find files distributed around a network and to facilitate electronic review, approval and release

[37] *Computer Aided Design Report*, December 1987, Pg. 8
[38] *Anderson Report*, March 1988, Pg. 7
[39] *Anderson Report*, April 1988, Pg. 3
[40] *Computer Aided Design Report*, December 1991, Pg. 11

 

of drawings. The initial version was released in early 1990 using the Ingress relational database management program.

Release 2.0 also supported Oracle. By 1993, this product was being called Information Manager. Drawings, model assemblies and related data were organized in folders much like today's Windows' file system. Data could be viewed by an authorized user even if it was checked out for modification by another user.

**Typical prices in late 1990**

Following are prices for some of the Unigraphics software modules in late 1990 on a per license basis:

- Basic Unigraphics II $15,900
- Surface Geometry $6,700
- UG Concept $9,700
- Hidden Line Removal $2,500
- Basic NC $7,200
- Advanced NC $15,600
- GRIP $10,000
- Infomanager Server $22,000
- Infomanager Client $2,200

McDonnell Douglas provided a floating license manager that resulted in customers needing fewer licenses, especially of infrequently used applications, than they had workstations. At this point in time two-thirds of the company's business was in the United States, a far higher portion than competitors such as Computervision and IBM.[41]

**EDS Unigraphics moves to meet PTC competition**

Starting in 1988 and picking up speed within a few years, Parametric Technology was revolutionizing the CAD industry with its Pro/ENGINEER software as described in Chapter 16. EDS recognized the impact PTC was having on its market as it saw customers switching from Unigraphics to Pro/ENGINEER. The need for significant changes to Unigraphics was very clear. As an example, in mid-1992, the company lost a 2,000 seat order at Caterpillar to PTC. The company needed to have a streamlined user interface, use solids as the basic geometric building block and incorporate dimension-driven parametric modeling. In the fall of 1992 EDS announced Unigraphics Version 10.0 with these features and with delivery expected to start in mid 1993.

The Version 10.0 story actually started back on March 17, 1988, St Patrick's Day. On the UGS History web site, John Baker does an excellent job of describing what went on that day and subsequently. (Note: at this point in time the official release level of Unigraphics was Version 5.1.

> "On March 17th, St. Patrick's Day (which turned out to be somewhat significant), there was a meeting in Cypress attended by key Development and Marketing personnel that would prove to be one of the most important gatherings in the history of the company. It was at this

[41] *Computer Aided Design Report*, October 1990, Pg. 2

 

meeting that a proposal was discussed about the need to produce a totally new product to replace Unigraphics. By this time it was generally acknowledged that a solid geometry based CAD system was highly desirable (remember this was before the acquisition of Shape Data) and that the company should begin to explore what it would take to accomplish that. Based on previous history, most people who walked into this meeting assumed that what we were really talking about was something that could be called UGIII however that did not sit well with the head of development, Bob Loss. It seems Bob had a strong aversion to naming this future product UGIII (you see at that time there was this feeling that products which carried a designation of "3" never quite turned out as well number "2" did, for example, look at how well the Apple III did). Anyway, Bob refused to let anyone use the word UGIII during the meeting since he was convinced that if we left the meeting with that name on our lips, that we would never be able to stop using it. So in order to avoid saying that "name" during the discussions that took place, the participants resorted to the use of a nonsense word, in this case "Kleenex Box" (there was one sitting in the middle of the conference room table) whenever they needed to say the "name" of the proposed new product. Well just before the meeting broke up someone commented that since it was St. Patrick's Day that maybe we could use that as inspiration. So this is how the "***Shamrock Project***" got its name.

Note however that while the Shamrock Project was originally intended to result in a totally new product, many factors became apparent over time which forced the company to slowly modify that vision to one where it was decided rather then pursuing a "revolutionary" process, that it would be more of a "radical evolution" of the existing Unigraphics II product. So while the original vision of that meeting was never realized, it started a series of events and activities that eventually lead to the development of Unigraphics V10.0. Remember that many forces were to come to play over the next several years, including the changing fortunes of McDonnell Douglas, the acquisition of Shape Data Ltd and the technology, as well as the ideas and vision of their people, that was now available, winning the GM business and the impact that their requirements suddenly had on the long term plans and then all of this coming to together with the sale of the Unigraphics organization to EDS in 1991. So in the end the impact of this meeting was akin to the proverbial stone dropped into the pond that started a ripple that eventually became a tidal wave.

However, there was one rather interesting legacy from that St. Patrick's Day meeting back in 1988. When the V10 project finally got into full swing, it was decided that as part of the marketing effort to position this product in the marketplace, that there would no longer be any use of the designation "Unigraphics II" in any company publication or marketing collateral."[42]

[42] http://www.plmworld.org/museum/the_80s.htm

Earlier versions of Unigraphics had utilized a Program Function Keyboard (PFK) as a primary command entry device similar to the unit used with mainframe-based CADAM. As the number of functions the software handled grew increasingly large, this resulted in an awkward user interface. Some commands were eight levels deep in the user menu structure. Version 10 dramatically streamlined the user interface. Menus were no more than three levels deep and the interface adopted the OSF MOTIF architecture (similar to Windows today). The result according to EDS was that some drafting tasks would require only 20 to 30 percent of the operations previously needed and that solid modeling could be done with 50 percent fewer operations. The problem was that this would require substantial retraining of users.

Unigraphics Version 10 used Parasolid Version 5.0 and was expected to be substantially faster for most modeling operations. The new software implemented model creation and editing techniques that were far more efficient than older version of Unigraphics. The most fundamental change was that solid modeling was now a core capability rather than an optional module. Trimming surfaces no longer required selecting surface edges in the right order. Version 10 also incorporated a constraint manager as part of the basic Unigraphics software, replacing the UG Concept software described earlier in this chapter. While Pro/ENGINEER worked only with fully constrained models, Unigraphics Version 10 worked with underconstrained models as well. In fact, the software would suggest constraints that could be accepted or rejected by the user.

The new software incorporated a true assembly modeler. Existing Unigraphics software required that the user copy parts into a single model. The new software took the more up-to-date approach of simply referring to component models. Changes to part models would subsequently be reflected in the assembly model. Drafting now had bi-directional associativity with the design model and the overall software suite had more comprehensive analysis software available, some developed in house while others were the result of strategic partnerships with companies such as PDA Engineering.

A sneak preview of Version 10.0 took place at the November 1992 Autofact conference in Detroit. One of the major changes to the user interface was that the new Unigraphics software no longer required a PFK device. Field testing of Version 10.0 started in March 1993 on Hewlett-Packard workstations running the HP/UX operating system. A controlled release began in October to customers who requested the new software but four months later at the 18th Annual Unigraphics Users Group meeting it still was not in full production. It was June 1994, when Version 10.3 was released, the new software could finally be considered ready for serious use.[43] The transition to the new implementation of Unigraphics turned out to be far from painless. Some applications such as NC would not incorporate the new user interface until Version 11. But nearly everyone agreed that this was the right way to go.

Perhaps indicative of the company's future direction, EDS Unigraphics did not try to do everything itself. Rather, the company developed an impressive list of business partners including Mechanical Dynamics, PDA Engineering, ICAD (conceptual design software), CGTech (NC verification software), Valysis (quality assurance software), Technomatix (robotics programming) and LightWorks Design (visualization). Typical Unigraphics Version 10 software configurations sold for $20,000 to $25,000 per seat.

[43] http://www.plmworld.org/museum/the_90s.htm

 

EDS Unigraphics announced in November 1995 that it planned to release a Windows NT version of Unigraphics in early 1996. Version 11.0 was released in January 1996 with enhanced surface modeling and expanded assembly modeling capabilities. A year later, Version 12.0 incorporated the new UG Scenario set of CAE products. Version 12.0 lasted just six months before it was replaced by Version 13.0 which implemented the company's new WAVE technology described below.

**AEC activity under EDS and afterwards**

As mentioned earlier, when EDS acquired McDonnell Douglas' CAD operation in November 1991, the AEC and mapping activity was set up as a separate organization, EDS/GDS Solutions, independent of the Unigraphics mechanical group. At first it was not clear that there was much of a future for GDS within EDS, but by mid-1992, led by Eric Loken, it seemed to be regaining some momentum. Other key players at the time were Kevin Sheehan who ran sales and marketing, Ray Pittman who was in charge of operations and John Emerson who handled research and development.

The overall group included about 320 people, some in Saint Louis but with most of the software developers in England. In 1992 EDS/GDS Solutions released a new PC version of GDS called MicroGDS. This was a Windows implementation that supported multiple user access to drawings, multi-window entity manipulation, and multiple drawings open in a single session. The software was originally developed in Cambridge England by CADCorp. It was priced at $3,500 and was sold by a direct sales force in that GDS Solutions did not have an established reseller organization at the time.

During a brief introductory period, the company offered a free copy of MicroGDS to buyers of a turnkey GDS system that included a Digital VaxStation 4000 which was priced around $25,000. GDS was also ported to the Hewlett-Packard Series 700 UNIX workstations since EDS coordinated all of General Motors' computer activity and HP was an approved platform at GM. Previously GDS had only been supported on Digital workstations but these were not approved for use at GM.

*A-E-C Automation Newsletter* ran an extensive two-part profile on EDS in its November and December 1992 issues. Several items become clear upon reading this profile.

- EDS/GDS Solutions believed that it could take EDS' expertise in managing large information technology projects and apply that experience to the AEC and mapping (GIS) markets.
- The focus was swinging away from GDS and the AEC market more towards the GIS market. The company's GIS software was feature-based rather than using traditional layer technology.
- EDS was built around large support contracts and selling $3,500 MicroGDS software packages against a mass marketer such as Autodesk just did not fit the profile.
- While GDS was a good drafting oriented package for civil engineering and architectural applications, the company lacked the complex plant design software that was needed to pursue heavy engineering and construction customers. GDS was never a factor in the world of large engineering companies such as Bechtel and Brown & Root.

 

- EDS/GDS Solutions had started working on a Advanced Traffic Management System that was built around the concept of a centralized traffic control center and intelligent highway sensors and traffic monitors. This activity would eventually end up as the basis for a Bentley Systems transportation management organization in Denver, managed by Pittman.
- The company did have some significant users. GDS was the preferred software at HNTB, one of the largest engineering firms in the country and it was also being used on two huge projects in Boston, the reconstruction of the Central Artery and the design and construction of the multi-billion dollar Deer Island waste treatment plant.[44]

It eventually became clear that there was no real synergy between GDS Solutions and EDS and in mid-1993 EDS sold the company to a group of outside investors led by Murray Holland, a Dallas lawyer. The company's named was changed to Graphic Data Systems Corporation and all 270 people then working in this area for EDS ended up with the new company including most of the existing management team. At the time, about 6,800 GDS licenses were installed at 1,200 companies and government agencies worldwide.[45]

This arrangement did not last long and in 1994, GDS was acquired by shareholders of EDS, GDS and UGC Consulting of Englewood, Colorado. The resultant company was called the Convergent Group. Graphic Data Systems Corporation continued as a separate wholly owned subsidiary of Convergent. In an article in *GIS WORLD*, GDS President Mark Epstein stated that the acquisition served two purposes. "It was a mechanism for UGC to leverage the consulting and financial resources of EDS. Also, GDS gets industry expertise in management and the sales cycle."

The GDS activity was moved to Colorado where it functioned separately from the existing UGC activities in the GIS arena. The GDS vice-president of product development at the time was Joe Astroth who subsequently ran Autodesk's GIS activity.[46]

In early 1997 Convergent decided that while its GIS activities were profitable, GDS as an on-going enterprise was not earning its keep. The company ceased further R&D investment and set out to find a buyer for the GDS portion of the company. By mid year it had an agreement with Informatix Software International, headquartered in Cambridge, England, to acquire the development and marketing rights to the MicroGDS and Piranesi product lines.[47] Piranesi was an interactive rendering package originally developed in the UK. As of 2006, these packages were still being marketed by Informatix.

**EDS Unigraphics at mid-life**

Five years after General Motor's EDS subsidiary acquired Unigraphics, many users and industry observers were still somewhat confused over the company's direction. Some believed that Unigraphics' primary interest was simply providing design technology to GM and its suppliers. Others were concerned that in consulting situations,

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[44] *A-E-C Automation Newsletter, November and December 1992*
[45] *Engineering Automation Report*, August 1993, Pg. 12
[46] Rajani, Purvi, *GIS WORLD*, December 1995
[47] *A-E-C Automation Newsletter*, May 1997, Pg. 3

EDS would automatically favor Unigraphics software even if was not the best fit for the client. Both of these perception were inaccurate.

EDS Unigraphics was very interested in expanding its customer base to encompass a broad range of users while EDS' consulting activities never seemed to involve Unigraphics to a significant extent except in regards to GM. By early 1996, there were nearly 45,000 seats of Unigraphics software installed at 4,500 customer sites worldwide. Less than 20 percent of this installed based was at GM and its suppliers.

Unigraphics executives including president John Mazzola talked extensively about the synergy between Unigraphics and EDS' consulting activity and how their combined resources could significantly benefit customers. This could cover everything from strategic planning to operational consulting and making the best use of emerging technology. EDS was even prepared to apply its "outsourcing" talents to taking over and operating a company's engineering computing infrastructure much like they did for GM. As good as all this sounded, it never really caught the imagination of large users and Unigraphics ended up functioning much like most other technical software firms.

Since 1993, Unigraphics had been working with customers helping them make the transition to Version 10. By 1996, about 80 percent had made the move. In the interim, a number of point releases had been delivered to users. Version 11 came out in early 1996 based on Parasolid Version 6.2. It contained extensive geometry enhancements, improved speed both in geometric manipulations and visualization and more comprehensive user development tools. Version 11 also contained improved assembly modeling capabilities.

Users wanted to work with increasingly complex models and computer performance was not keeping up with this requirement. Unigraphics compensated for this by filtering assembly model data and loading just a subset of information that the user needed for the task at hand. As an example, if a user was working on a small subassembly only the data needed to detect interferences with the rest of the model needed to be loaded.

By early 1996, Unigraphics was starting to get more serious about product data management. Two products were being offered. UG/Manager provided multi-user access to part and assembly data for small workgroups while IMAN was intended for larger design groups and those who needed this data in other departments. There was a conflict within the company in that some wanted IMAN to be positioned as an enterprise-wide solution while other saw it as having more limited capabilities.

With Version 11, Unigraphics was available running under Windows NT on both Digital Alpha and Intel platforms as well as on traditional UNIX platforms. The NT implementation had the look and feel of the UNIX workstation version. Initially, just basic design and drafting was available on this new operating system. It took most of 1996 to complete the port to Windows NT.[48]

On June 7, 1996 GM completed the spin-off of EDS as an independent company with Lester M. Alberthal Jr. as CEO. The expectation was that this would provide EDS Unigraphics with more flexibility to pursue non-GM business. As part of the spin-off, EDS negotiated an agreement with GM to standardize on Unigraphics software, consolidating some 26 different systems then in use and to eventually install an additional 10,000 seats of Unigraphics software. During the first six months of 1997, 2,100 new seats were installed bringing the total to 7,000.

[48] *Engineering Automation Report*, February 1996, Pg. 6

 

By March 1997, the company was shipping Unigraphics Version 12 which implemented bi-directional associativity between design and analysis modules under the UG/Scenario nomenclature. Unigraphics started reporting a fairly steady stream of new accounts including Bell Helicopter, VisionAire, Ericsson and the Swiss technical university, ETH Zurich.

**EDS Unigraphics out from GM's shadow**

Throughout its entire life, Unigraphics had existed in the shadow of a much large industrial companies, first McDonnell-Douglas and then General Motors. Although EDS was a multi-billion dollar enterprise, at least it was in the computer services industry and its top executives intimately understood the dynamics of that business even if they did not have a similar grasp of the CAD industry. In the year or so after the EDS spin-off from GM, EDS Unigraphics seemed to shift into a higher gear and achieve a momentum they have maintained ever since.

Because the company had been owned by GM, it had been very difficult for Unigraphics to obtain major business from other automotive OEMs. They had, however, shipped over 6,000 seats of Unigraphics software to more than 950 automotive component suppliers. On the other hand, Unigraphics was doing well in the aerospace sector with major orders from BE Aerospace, British Aerospace, Ilyushin, Antonov, Northrop and Boeing Defense.

More and more, Unigraphics marketing emphasized enterprise-level productivity. One tool towards this goal was greater ability to share data between applications. The company called this the "Product and Process Pipeline" which consisted of the Parasolid solid modeling kernel, IMAN product data management and Internet/intranet communications. Over the next seven years the company would redefine and refocus this concept but even by the fall of 1997 the strategy was well in place.

Unigraphics Version 13 introduced an exciting new tool for top-down engineering design. WAVE (What-if Alternative Value Engineering) was a technique for defining a complex product such as an automobile in a way that enabled designers to make fairly significant changes and have these changes propagate throughout the entire model. Two key elements of WAVE were the WAVE Associativity Manager and the Visual Editor. As an example, once an automotive model was built using these tools, it was possible to change the wheelbase on the vehicle and have it go from being a four-door sedan to a two-door coupe.

Within basic Unigraphics, the company emphasized new sketching techniques, virtual product mockup, high performance visualization and the start of integrating design with analysis. The visualization used an Hewlett-Packard developed concept called DirectModel. By 1997 Unigraphics had ratcheted up its relationship with HP to the point where it had become one of the strongest and longest lasting strategic partnerships in the CAD industry. About this time, Unigraphics also began offering lower cost versions of its software including UG/Creator for $5,995 and UG/Designer for $9,995.[49]

**Parasolid becomes an accepted component technology product**

Prior to the early 1990s, every CAD software vendor developed its own geometric modeling core. In fact that is what most companies thought distinguished them from their

[49] *Engineering Automation Report*, September 1997, Pg. 6

 

competitors. Spatial Technology, now a Dassault Systèmes subsidiary, was the early leader in providing geometric modeling software with its ACIS product. Unfortunately, ACIS suffered from a lack of geometric completeness, the timeliness of new releases and quality issues.

In 1994, SolidWorks switched from the early use of ACIS to EDS Unigraphics' Parasolid prior to the release of SolidWorks 95. Most other vendors were initially reluctant to follow suit in that they were concerned about using such a critical piece of software when it was controlled by a competitor.

As Parasolid became a more and more important element of Unigraphics software, EDS/Unigraphics acquired Parasolid as noted earlier and invested significant resources in improving the geometric coverage and performance of the software. By 1997, problems with ACIS were serious enough that additional vendors decided to make the switch to Parasolid including Bentley and Intergraph's Solid Edge business unit.

**EDS Unigraphics acquires Intergraph's mechanical business unit**

In October 1997, EDS and Intergraph announced that they planned to form a new company consisting of Intergraph's mechanical business unit, Unigraphics and a small amount of EDS' consulting activity that was directly related to supporting Unigraphics. EDS would own the majority interest in this unnamed company while Intergraph and the company's employees would own minority interests. Altogether, the company would have a little over 2,000 employees, 350 from Intergraph and 1,700 from EDS Unigraphics.

The Intergraph activity consisted of both the company's older EMS software as well as Solid Edge, a new mid-range mechanical CAD package. There never was any question but that the plan was to encourage EMS users to switch to either Solid Edge or Unigraphics. This was particularly important in regards to the large Navy CAD-2 contracts Intergraph had won in the early 1990s. According to John Mazzola, the Intergraph group would function as a separate activity with its own product development and marketing.

Mazzola expected the new company to do between $400 and $450 million in 1998 of which $80 million would be hardware resale. He saw the two products targeted at different market segments, Unigraphics at its traditional large manufacturing firms while Solid Edge would focus on smaller manufacturing companies.

Since Unigraphics used Parasolid as its modeling kernel and Solid Edge planned do the same with Release 5.0 due out in the March 1998 timeframe, it seemed that Unigraphics would be better able to integrate the two packages together than would Dassault with CATIA and SolidWorks which used dissimilar modeling kernels. That definitely proved to be the case.

**UGS Goes Public and Completes Intergraph Mechanical Acquisition**

In subsequent months the planned deal with Intergraph changed significantly. Instead of establishing a jointly owned new company, EDS restructured EDS Unigraphics in early January 1998 as a separate enterprise called Unigraphics Solutions with John Mazzola as its president and CEO. This entity then purchased Intergraph's mechanical systems business unit, including both Solid Edge and EMS, for about $100 million which EDS loaned the new company.

 

EDS then sold three million shares of Unigraphics Solutions to the public at $14 per share on June 18, 1998. EDS still retained control over UGS since each share of stock it owned had ten votes compared to a single vote per share for those shares owned by the public. One negative aspect of the establishment of an "independent" company was that Unigraphics Solutions (or UGS as most people referred to it) received none of the sales revenue from the previously mentioned 10,000 seats of Unigraphics sold to GM although it did subsequently receive substantial maintenance and support revenue.[50]

After acquiring Solid Edge, UGS implemented a four-prong business strategy consisting of Parasolid, Unigraphics, Solid Edge and IMAN. In 1998 revenues were running at about a $400 million annual rate and the company had nearly 80 sales offices around the globe.

Under UGS, the Solid Edge product seemed to thrive, much as SolidWorks was under Dassault's ownership. Some people apparently did know how to make high-tech acquisitions work. UGS focused Solid Edge on the machinery industry, particularly companies that built manufacturing equipment. This market segment did not require complex surface geometry but it did require that the software handle large assemblies. By late 1998 assemblies with 5,000 parts were being handled by Solid Edge without any obvious problems. The Solid Edge team demonstrated fairly quickly that they were comfortable with this business concept.

Technically, Solid Edge personnel focused on making the software easier to use. One result of this was Solid Edge STREAM technology which used inference logic to predict user interactions. Solid Edge Version 6 was released in December 1998 with additional modeling enhancements, a sheet metal design module and new capabilities intended to facilitate the design of plastic parts.

Modeling now included the ability to drag-and-drop features. Gradually, the company was also improving Solid Edge's surface geometry functionality. With Solid Edge Version 6 and Unigraphics Version 16.0, the two packages were able to read each other's part files and could incorporate the other's parts into assemblies. By early 1999 the company was shipping 1,000 copies of Solid Edge a month and had a number of customers with over 100 copies.

UGS never had any intention of enhancing EMS or soliciting more customers for that software package. Basically it went on life support. The largest EMS customer by far was the U.S. Navy in that Intergraph had won the lion's share of the Navy's CAD-2 procurement in the early 1990s. Initially, the Navy had purchased Intergraph UNIX workstations with EMS and MicroStation software. When the Navy decided to switch to Windows NT PCs to save money, EMS could no longer be supported. The contracts were modified so that UGS was able to provide Solid Edge and Unigraphics to Intergraph Federal Systems which in turn provided the software to the Navy.

By early 2000, the company had shipped 20,000 copies of Solid Edge and was delivering Version 8 with significant assembly design enhancements.[51]

### Interest in PDM heats up

By 1998, Product Data Management was taking on increased importance at UGS. The company's primary PDM software, IMAN, had an extremely strong data architecture

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[50] *Engineering Automation Report*, August 1999, Pg. 9
[51] *Engineering Automation Report*, March 2000, Pg. 5

that facilitated the implementation of solutions that covered distributed user groups and had excellent integration with Unigraphics plus the ability to handle non-UGS data. When IMAN Version 4 was released in late 1997, UGS introduced Distributed IMAN (D-IMAN) which facilitated the distribution of product data across multiple sites of an enterprise. In mid-1998, UGS released IMAN V5 which incorporated numerous enhancements to D-IMAN and other modules of this product suite.

D-IMAN enabled users at any site to find necessary files by performing a remote find operation on the IMAN Object Directory Services (ODS) database. The ODS acted as a master index for all the information the different sites wanted to publish and make available to authorized users. Each site or development team decided when it wanted to release design data and who they wanted to share it with. There were tools in IMAN that facilitated much of the process such as automatically releasing a certain class of documents once the design had reached a particular state of approval.

High-speed communication services were just becoming readily available at that point in time and accessing project data from sites distributed over a large geographic areas was still extremely time consuming. Networks were easily overburdened by constant activity between uses and remotely located files. D-IMAN resolved this problems by using a process of controlled replication. Data created at remote locations was readily available through the ODS. Replication was synchronized at times that were convenient for each site.

Analysts such as Wayne Collier of D.H. Brown stated:

> "The federated capabilities of the D-IMAN module provide the kind of flexibility that large-scale customers need to manage product information in a distributed enterprise. D-IMAN allows customers to model the rules and data structures that are unique to each individual site in a federation – an essential component of virtual enterprises."[52]

IMAN V5 also incorporated new Web functionality that eliminated much of the need to develop and support different software for each client machine type supported by IMAN. The company considered this to mean that IMAN was “Web-enabled.” The next release, Version 6, was to be Web-centric” rather than just Web-enabled. In addition to the full implementation of IMAN that UGS continued to provide, a stripped-down version called UG/Manager as described earlier was also available.

**UGS starts flying on its own**

Although EDS continued to own a controlling interest in UGS, there was little evidence that EDS exerted much influence on the company’s day-to-day operations. As an example, in September 1998 UGS held the first of a series of annual briefings for the media and industry analysts. Held in Newport Beach, California, there was little presence by EDS management and only one presentation by someone from EDS extolling the potential synergy of the relationship between the two companies. As much as they talked about that synergy, it seems like it rarely occurred.

Unigraphics Version 15 was targeted for release in late 1998. This release had a user interface that conformed more closely to the Windows NT style, a significant

[52] *Engineering Automation Report*, September 1998, Pg. 6

enhancement considering that nearly 50 percent of Unigraphics software shipments were the NT version. Parasolid was also gaining momentum although it only amounted to about 2 percent of UGS' overall revenue. In particular, UGS was having some success licensing Parasolid to NC software firms including Gibbs, DP Technology and CNC Systems. New versions of Parasolid continually enhanced the kernel's geometric coverage, performance and reliability.

The company's analyst briefing in July 1999 was particularly upbeat. Mazzola stated that the company had received 25 orders in the first half of the year that involved 50 or more seats of software or over $1 million of total revenue. UGS was in the process of phasing out the resale of computer hardware and for a while, this put a damper on the company's overall sales growth but it was a necessary move as reselling hardware was quickly becoming a profitless business for systems companies like UGS. At the briefing, the company was very enthusiastic about Solid Edge, IMAN and Parasolid. One could see that UGS was quickly becoming a premier vendor in the industry and one concern among writers and analysts was that EDS didn't do anything to screw it up.

In early 2000 UGS began shipping Unigraphics Version 16. In addition to many hundreds of individual enhancements, this was the first release that was developed using Windows NT as the primarily programming environment. In the past, the UNIX version was developed and then converted to run under Windows NT. From this point forward it was done the other way around. The most significant new application was DesignStudio which provided high-end surface design commonly associated with industrial design software such as Alias Studio and CDRS (which had recently been acquired by PTC and renamed Pro/DESIGNER.). The other major emphasis of Version 16 was what UGS was now calling "Predictive Engineering." There were three components that made up this initiative:

- process wizards that facilitated the design of standardized processes such as mold design
- analysis
- optimization and design capture.[53]

The following month UGS surprised many in the industry when it acquired what was left of Applicon (See Chapter 7) for $10 million, mostly to obtain that company's programming talent in Ann Arbor, Michigan. Eventually, most Applicon users switched to Unigraphics and/or Solid Edge.

General Motors continued to be a major part of UGS' business. Although the company did not receive any of the revenue from the 10,000 licenses GM purchased from EDS just before UGS was spun off as an independent company, it did garner substantial service and support revenue. In June 2000, GM awarded UGS a $139 million contract for additional software and services.

This was probably the largest non-government contract in the history of the CAD industry. The primary software covered by the contract was 30,000 seats of iMAN (nomenclature had been changed from IMAN), many of which had already been installed. In actuality, this contract covered the prior year as well as the next two years. By mid-2000, GM had over 8,600 seats of Unigraphics software installed and most legacy systems had been phased out.

[53] *Engineering Automation Report*, February 2000, Pg.12

**UGS in the 21st century**

In late June 2000, John Mazzola announced that he would be retiring in early 2001 after 35 years with UGS and predecessor incarnations of the company. Then, on July 12th, a second UGS press release stated that Tony Affuso, who had been made COO when Mazzola announced his pending retirement, had been named President and CEO effective immediately and that Affuso was also assuming Mazzola's seat on the Unigraphics Solutions Board of Directors.

The first reaction was that Mazzola was being prematurely pushed out. That turned out not to be the case. At the 2000 summer analyst meeting, Mazzola said that he had originally stated that he would retire on March 31, 2001 or when a replacement was found (the last point was left out of the June press release). He also stated that he encouraged the board to give Affuso the job and the Board went along.

Tony Affuso was the Executive Vice President of Products and Operations and COO at the time he was promoted to CEO. He had joined Unigraphics in 1991 when EDS acquired the company from McDonnell Douglas. Prior to that, Affuso had been with EDS working on the implementation of the C4 project at GM. As a bit of trivia, he had been a manger at Xerox where, in 1983 he was part of a team that evaluated CAD systems including Unigraphics but selected a non-Unigraphics system.[54]

At the 2000 analyst meeting Mazzola (Affuso was not at the meeting due to a travel conflict) spent a fair amount of time discussing the company's success in growing revenue while at the same time being extremely profitable. While the overall industry had been struggling to grow much more than 10 percent annually during the previous few years, UGS had been growing by better than 25%. This was in spite of the fact that the company had been exiting the hardware resale business. In the two years since UGS went public, the company had grown from 5,600 customers to over 13,500.

Figure 19.10
Tony Affuso

Mazzola was frustrated by the fact that Wall Street failed to recognize the company's accomplishments and its potential. UGS stock sold for just 14 times earnings and a little more than one times revenue while Dassault Systèmes sold for over 100 time

[54] http://www.plmworld.org/museum/the_00s.htm

earnings at the time and nearly 20 times revenue. A major problem was that EDS still owned 86% of UGS and controlled 98% of its voting rights.[55]

## Adding high-end visualization software

The next major development occurred on September 5, 2000 when UGS and Engineering Animation Inc. jointly announced that the two companies had reached a definitive agreement allowing UGS to acquire EAI in a cash tender offer expected to be worth about $205 million. The agreement called for shareholders of EAI to receive $13.75 cash for each share of EAI common stock owned, 18 percent more than what the stock had previously been selling for.

EAI was a well respected vendor of high-performance graphic visualization software that had run into some financial difficulties due to problems with how revenue was being booked. By the time UGS agreed to acquire the company, most of these problems were behind it and EAI was regaining financial viability.

The initial plans were that EAI would be financially structured as a subsidiary. Key EAI executives including vice president Martin Vanderploeg, one of the founders of EAI, and vice president and CTO Jeffrey Trom planned to remain with the company while chairman and CEO Matthew Rizai EAI left the company. Eventually EAI became the focal point for UGS' factory automation and visualization activities under the E-factory brand. This acquisition also added EAI's JT interoperability data format to UGS' product offering.

Meanwhile Solid Edge continued to pick up momentum. In 1999 the company had initiated a marketing program called Solid Edge Origin under which it had distributed 900,000 copies of a stripped down version of Solid Edge. 120,000 recipients took the time to register to use this software and an unreported number ended up converting to the full Solid Edge package. The Solid Edge business unit, which was still managed by Bill McClure, continued to focus on the machinery manufacturing industry.

In 1998 the company had touted the fact that Solid Edge could handle assemblies with nearly 15,000 discrete parts. By late 2000 this number was up to 60,000. Solid Edge Version 9 began shipping in November 2000 with a new optional Engineering Handbook module developed by MechSoft.com of Austin Texas. The company also introduced software for converting two-dimensional drawings to three-dimensional models. Initially this software, Xpand3D, was based on technology developed by Manufacturing and Consulting Services (see Chapter 15) but was eventually replaced with internally developed software.[56]

The company's name was changed once again in early 2001, this time to simply UGS. The move reflected the fact that UGS developed and marketed more than just Unigraphics software. At about the same time, world headquarters for UGS was moved from St. Louis to Cypress.

## Acquisition of SDRC and a major corporate restructuring

On May 23, 2001 EDS announced an agreement in principal to purchase Structural Dynamics Research Corporation (SDRC) for approximately $950 million in cash, or $25 per share. Concurrent with that purchase, EDS also planned to buy the 14

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[55] *Engineering Automation Report*, August 2000, Pg. 9
[56] *Engineering Automation Report*, November 2000, Pg. 4

 

percent of its UGS subsidiary that was publicly held. That offer to the UGS stockholders was expected to be $27 per share or approximately $170 million. After complaints from UGS stockholders that the price was too low it was subsequently raised to $32.50 per share. It would end up taking until October 1, 2001 for EDS to complete the acquisition of SDRC and the outstanding UGS stock.

The new company was initially known as EDS PLM Solutions. At the time the deal was first announced, EDS stock was selling for about $60 a share. In mid-2002 EDS ran into some accounting problems of its own that pummeled the company's stock. The share price dropped to just above $10 per share before recovering to about $25 in mid-2006. This would eventually have a major impact on the future of EDS PLM Solutions.

The result of these two transactions was UGS was once again wholly owned by EDS but was now be a much larger enterprise. The plan was to combine the two companies under the UGS name as EDS' fifth line of business, albeit as the smallest of the five. Tony Affuso, UGS president and CEO, became the president of this new EDS business unit with more than $1 billion in reported annual revenues.[57] Headquarters were moved to Plano, Texas in order to be closer to EDS headquarters.

More details of the merger were described at the annual UGS press and analyst meeting that July. Of the 24,000 customer UGS and SDRC had, only about 1,000 were customers of both firms according to Affuso. Chuck Gindstaff, who then had the title of executive vice-president of operations at UGS, described in detail to the attendees how they planned to merge I-DEAS and Unigraphics. The plan was to release several additional versions of the two packages with increasingly tight integration between them until around the third major release, I-DEAS and Unigraphics would be one and the same. In mid-2001, I-DEAS Version 9 and Unigraphics Version 18 were both close to being released but they were able to add improved geometry exchange capabilities before the software actually shipped.

Part of the integration plan included increased use of the JT data format UGS had picked up when it acquired EAI and was used to produce lightweight tessellated data used by iMAN and some visualization programs. The other important exchange format was the eXT format which was an XML wrapper around the Parasolid XT format. There were several presentations by EDS executives trying to explain why the new combination of SDRC and UGS under the EDS banner would lead to a significant increase in large scale systems integration business.

While both company's had strong CAD/CAM solutions, SDRC was stronger in the integration of analysis software into the design process and its Metaphase software was significantly stronger than UGS' iMAN product. On the other-hand, SDRC had been unable to penetrate the mid-range market and had nothing comparable to Solid Edge. SDRC brought Ford and Nissan to the table while UGS, of course, counted GM as its premier customer. Overall, the two companies complemented each other fairly well, especially if they could follow through on the I-DEAS/Unigraphics strategy described by Grindstaff.[58]

The new generation of software was subsequently given the NX designation. First out of the chute was Unigraphics NX (what under other circumstances would have been referred to as Version 19). The NX stands for NeXt generation software. Announced on

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[57] *Engineering Automation Report*, June 2001, Pg. 3
[58] *Engineering Automation Report*, August 2001, Pg. 3

 

October 8, 2002, Unigraphics NX came with an easier to use user interface, knowledge-driven task automation tools, better capabilities for editing models imported from other CAD systems and improved tools for exchanging models with I-DEAS.

Over the next several years, the company met most of its NX delivery goals, both for timeliness and content. Unigraphics NX 2 came out in August 2003 with improved usability, enhanced knowledge-based design and better data exchange. The intent was not to translate I-deas (the new EDS nomenclature for I-DEAS) models but to basically rebuild them in Unigraphics starting with the I-deas history and feature data.

About the same time, the company released Solid Edge Version 12 which also had an improved user interface as well as enhanced assembly modeling capabilities. In Version 12, EDS replaced the original two-dimensional to three-dimensional conversion tool from Version 9 called Xpand3D with a new Create 3D tool that worked much better.[59]

By late 2002 Solid Edge was probably a match for SolidWorks in most areas other than advanced surface modeling. The Solid Edge business unit decided to skip Version 13, especially after the problems Autodesk had with AutoCAD R13. Version14 was announced in early 2003 with significant enhancements to surface modeling. Solid Edge customers were now building models with over 100,000 individual parts. With this release, Solid Edge could now exchange data more effectively with I-deas.[60] By the time Version 15 was released in late 2003, Solid Edge compared favorably with main stream design packages of just a few years earlier.

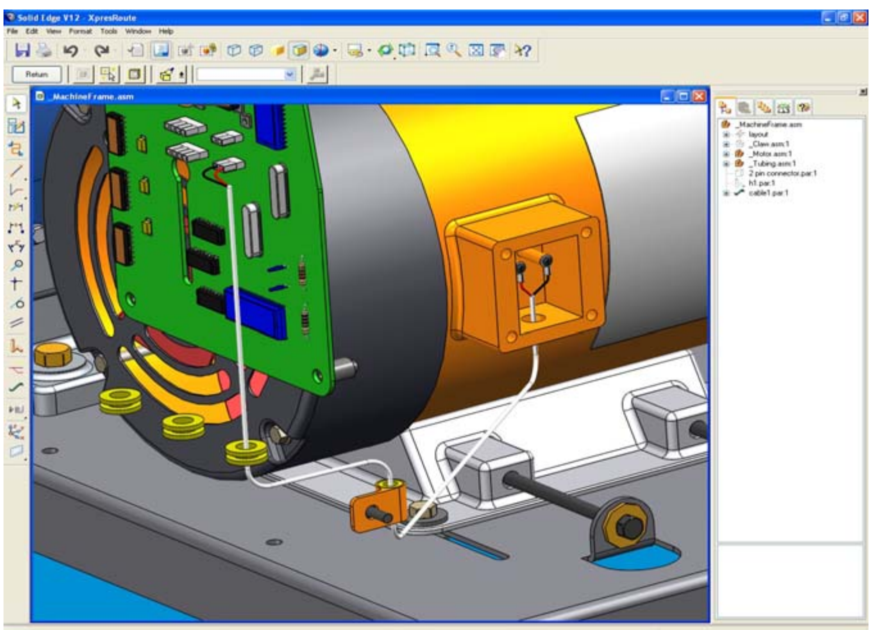

Figure 19.11
Solid Edge Version 12

[59] *Engineering Automation Report*, November 2002, Pg. 3
[60] *Engineering Automation Report*, March 2003, Pg. 4

 

**Two More Changes in Ownership**

On November 11, 2003, EDS announced the EDS PLM Solutions would henceforth be called UGS PLM Solutions. (At this point I have lost track of the number of times the name for this business activity has been changed.) A month earlier, EDS had announced that it was planning either a new IPO or a private offering for a minority stake in the company. EDS' own financial problems were probably the driving factor behind this announcement.

After reporting disappointing financial results for 2003, EDS announced that it was considering the sale of UGS PLM Solutions after receiving what it termed significant interest from several parties.[61] On March 14, 2004 EDS announced that it had reached a definitive agreement to sell its UGS PLM Solutions unit for $2.05 billion in cash to a group of three private equity firms: Bain Capital, Silver Lake Partners, and Warburg Pincus. UGS at the time had annual revenues of about $900 million and earnings of just over $100 million. The sale closed on May 27, 2004 and the company's name was changed to UGS Corporation with Tony Affuso continuing as president and CEO. Each of the investors had an equal stake in the company.[62]

The software migration to NX continued on schedule with the release in April 2004 of I-deas 11 NX Series. From a business point of view, a significant development was the acquisition of Cambridge, England-based D-Cubed, Ltd., a developer of well respected constraint management software used by many CAD vendors. It nicely complemented the company's Parasolid software.

One of the interesting aspects of the new UGS was that in spite of the fact that it was privately owned it decided to release quarterly financial data. Revenues for the quarter ending June 30, 2004 were up 11 percent to $236 million with operating profits of $29 million. During a conference call discussing the company's results, Affuso was particularly upbeat about the company's prospects, especially in regards to its PLM opportunities. He gave five reasons users were poised to more aggressively install comprehensive PLM solutions:

1. Companies are now interested in generating greater sales, not just in lowering costs.
2. Manufacturers want to streamline their business processes.
3. Competitiveness means enhancing product commonality and reusing components (up to 50 percent in the automotive industry).
4. Strategic partnerships are increasingly important.
5. They want a single source of process information.

According to Affuso, if you looked at the most basic PLM component, the managing of engineering documents, only about 30 percent of the company's customers were doing this adequately. As you explore more complex aspects of PLM such as configuration management, that percentage went down dramatically. The basic message was that was still a lot of room for growth of the business.[63]

On September 15, 2004 UGS announced NX 3, the timely culmination of a three-year project to bring together the company's Unigraphics and I-deas software in a single

[61] *Engineering Automation Report*, March 2004, Pg. 8
[62] *Engineering Automation Report*, April 2004, Pg. 1
[63] *Engineering Automation Report*, August 2004, Pg. 10

product. NX 3 is the version in which I-deas users were able to migrate data without the need for data translators. Instead of translation, NX 3 regenerated I-deas geometry using the same algorithms used in I-deas itself. The software was not only able to read I-deas three-dimensional part and assembly models, but also read drawing files with complete fidelity and maintain the associative relationships between models and drawings.[64]

Then in January 2007, UGS Corporation announced that it was being acquired by Siemens AG for $3.5 billion – a nice profit for the three private equity firms that had paid a little over $2 billion less than three years earlier. UGS was initially renamed UGS PLM Software and became part of Siemens' Automation and Drives Division when the deal closed a few months later in May 2007. Affuso remained chairman and CEO of the company although two senior Siemens executives joined the company, Tilo Brandis as president and Peter Bichara as executive vice president and CFO.

In mid-2007, UGS began shipping NX Release 5 with a stripped down user interface, emphasis on handling large assemblies efficiently and direct model editing that avoided some of the problems of pure history-based modeling and enabled users to directly edit existing geometry. Brandis was unable to permanently join the UGS team in Plano, Texas due to family health reasons and was replaced as president by another Siemens executive, Dr. Helmuth Ludwig. Of course the acquisition required one more name change, this time to Siemens PLM Software.

As this is being written, it is too early to tell how similar the Siemens acquisition will be to General Electric's disastrous acquisition of Calma more than 20 years earlier as described in Chapter 11, but so far it seems to be working well.

[64] CADCAMNet.com, September 16, 2004

# Chapter 20

# Tom Lazear and VersaCAD

Tom Lazear joined Southern California Gas Company in 1957 after receiving his B.S. in mechanical engineering from the University of California (Berkeley). His position was as an Associate Design Engineer working on the design of piping systems, pumping stations and similar projects. He then joined Fluor Corporation in 1959 as an associate computer engineer.

After taking a week long programming course, he began working with one of Fluor's senior structural engineers, Eli Czerniak, who had fought for Israel's Haganah during its war for independence in 1948 and then emigrated to America. Czerniak had recognized the potential of digital computers for solving engineering problems and once Lazear started working for Fluor, Czerniak decided that they would work together to develop a series of structural analysis and design programs.

In 1959 Fluor was using a Burroughs Datatron 205 computer. This machine was originally developed by Consolidated Electrodynamics Corporation (CEC) whose ElectroData division was subsequently spun off and went public. ElectroData was then acquired by Burroughs in June 1956 and became a key component of that company's subsequent computer activities.

The Datatron 205 was a vacuum tube machine that had a drum memory with 4,000 10-digit word capacity. The primary means of input and output was via a punch paper tape Flexowriter which also served as a console printer. The Datatron 205 was a fairly advanced machine for its time with index registers, floating-point arithmetic and magnetic tape data storage. It was physically quite large, nearly filling a 20' by 30' room, and requiring 20 tons of air conditioning. In many respects, the Datatron 205 was comparable to IBM's 650 although the Datatron machine was physically much larger and cost considerably more.

The programs Lazear and Czerniak created facilitated the design of reinforced concrete foundations for vertical and horizontal pressure vessels as well as the design of pressure vessels themselves. The foundation programs calculated the size of the foundations as well as the reinforcing steel needed based upon fairly straightforward input data provided by the design engineer. One form of output included specific dimensional data printed out on small sheets of vellum which were then attached to full size drawing sheets. These programs were documented in publications such as *Petro/Chem Engineer*[1] and *Consulting Engineer*[2].

The first automated drafting application Lazear was associated with involved producing isometric piping diagrams on a Stromberg Carlson SC4020 film recorder. The process involved writing instructions for how the piping was to routed, keypunching the information and then processing those punch cards on a mainframe computer. The computer generated instructions on magnetic tape which was then used by the SC4020 to produce film images. The film was reproduced on a Xerox Copyflow machine to create

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[1] *Petro/Chem Engineer* February 1962

[2] *Consulting Engineer* August 1961 and March 1963

vellum drawings. Fluor invested about a year of effort in developing this process. According to Lazear, it was "pretty awkward and never quite made it as a production system."[3] It wasn't until ten years later when Fluor acquired its first M&S Computing (Intergraph) system that computer generated isometric drawings became practical.

While working for Southern California Gas Company and Fluor, Lazear picked up a MS degree in electrical engineering from UCLA. As the use of computers became more prevalent at Fluor, Lazear became responsible for much of this activity. In 1968 he became director of computer services for the company, a position that would probably be called CIO today. After going back to school and receiving an MS degree from MIT's Sloan School of Management, Lazear became an assistant to the senior vice president and general manager of Fluor's Southern California Division. He served in this role until 1979 when he left to join T&W Systems on a full-time basis.

**Early days at T&W Systems**

T&W Systems was started as a part-time endeavor in 1977 by Lazear and William Yunek. (Lazear says he would laughingly tell people that T&W stood for Tom and Wife but that a woman's rights person objected so that he stopped doing it.)[4] The initial staff at T&W consisted of Tom Lazear, his wife Sandy, his daughter Debbie who was a student at the University of California Irvine (UCI) and his son Mike who was a freshman at Cal State Long Beach (CSLB).

The first software developed by T&W Systems was a medical billing application. Sandy Lazear worked for an orthopedic surgical practice where William Yunek was the office manager. The doctors from this practice invested $30,000 to help get T&W Systems started.

Lazear did an extensive review of available computer systems prior to starting work on the medical billing system and eventually selected a CADO computer for this application. It had 8" floppy drives, a big monitor and a simple operating system that used a combination of COBOL and Basic. The Lazears took a programming course on a Saturday in 1977 and began work on the billing application the following Monday. They invested about 1,000 manhours in the software and sold the first copy for $5,000. A few additional systems were sold but the product was not sufficiently successful to base the future of the company on it.

The focus subsequently switched to the developing of piping design software and eventually Computer-Aided Design software. Lazear realized that they needed a more powerful computer for these applications and had actually purchased a Digital PDP-11 with an RSX-11 operating system and a FORTRAN compiler in 1976. It sat in a box in his home unopened while they looked for an office in which to house T&W Systems.

At some point in 1978, Lazear met the local salesman for Terak, Dick Mitchell, who convinced him that the Terak was the right computer system for T&W to use. The first software the company developed for this machine was a piping isometric drafting package they called T-Square. The software was sold to about half a dozen companies during the late 1970s. Unfortunately, isometric drafting software appealed primarily to

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[3] *Computer Graphics,* February 2001
[4] Email from Tom Lazear, March 7, 2003

 

large design firms and these companies preferred to buy key applications from major CAD players such as Intergraph and Calma.[5]

About the same time the company began the development of its first general purpose CAD drafting product which was also called T-Square (sometimes referred to as Electronic T-Square). It was initially shipped to users in late 1979 and went into production mode in 1980 at the University of Arizona in Tucson where it was used for a course called Introduction to Computer Aided Design.[6] Ever since then, the software and its derivatives has been well thought of as an educational tool.

Terak was a small computer company in Scottsdale, Arizona, founded by Bill Mayberry, Dennis Kodimer and Brian Benzar. Its primary product was the Terak Model 8510/a which was the machine used by T&W for T-Square. It was based upon the Digital Equipment Corporation LSI-11/03 16-bit processor. The Digital PDP-11 was a fairly substantial machine that was marketed by Digital in several different versions. The LSI-11/03 was primarily an OEM product.

A Terak 8510/a could support up to 128KB of main memory if the 11/03 was replaced with a LSI-11/23. Hard disks up to 40MB in capacity were also available. A basic 8510/a was priced at $8,935 with a monochrome 320 x 240 resolution display. A color version of the machine was also available with 8-color 640 by 480 resolution for an extra $10,550.[7]

Figure 20.1
Terak Model 8510/a

The Terak computer incorporated the UCSD Pascal or USCD-P operating system developed at the University of California at San Diego by Dr. Kenneth Bowles. This operating system was also available as an option on the Hewlett-Packard HP9836 and HP200 series workstations, the Apple II and the IBM PC. Programs written in Pascal were compiled into “p code” (the p stood for pseudo code not Pascal code) which was stored in a compact ASCII format. This p code was then executed using an interpreter which ran in the UCSD-P operating system environment. According to Lazear, the result was fast executing code that could be easily overlaid with new modules in main memory as needed.

[5] Email from Tom Lazear, March 15, 2003
[6] Email from Tom Lazear, March 7, 2003
[7] http://www.threedee.com/jcm/terak/

In 1979, Lazear quit Fluor and joined T&W Systems on a full time basis. The UCSD-P programming environment was somewhat difficult for programmers to get their arms around. Lazear decided to send the entire programming team to Salt Lake City where they met for two days with Dick Brant, a professor at the University of Utah. Brant was an expert in using UCSD-P and had written a number of programs for the Terak system. He taught the T&W programmers how to develop graphic applications on the Terak and how to structure large programs for that machine. According to Lazear, "That little trip paid huge dividends."[8]

A T-Square system including a Terak 8510/a with 64KB of memory, two floppy disks, a Houston Instruments HIPAD 11" tablet, a Houston Instruments HIPLOT DMP-7 11" by 17" plotter and basic drafting software was priced at $23,500.[9] This was at a point in time when most minicomputer-based systems sold for upwards of $125,000 per seat. T-Square software was targeted at schematic drafting applications such Process and Instrumentations Diagrams (P&IDs). The first trade show that T&W Systems attended as an exhibitor was COMDEX in the fall of 1981 where the company displayed T-Square in the Terak booth. This was followed by A/E/C SYSTEMS in Chicago in the spring of 1982.

**T-Square is ported to the Apple II**

T&W reprogrammed T-Square for the Apple II computer and introduced it as CADapple in May 1982. Apple was a hot computer company and the decision to support the Apple II rather than the IBM PC was a logical decision at that time. History would eventually prove otherwise. A CADapple system including an Apple II computer with 48KB of memory, two floppy disks, a joystick for cursor control, a Houston Instruments DMP-7 plotter and software sold for $9,995. A tablet cost an additional $1,000 while the software alone sold for $2,475. By 1983, CADapple was the number one selling CAD package on the Apple II with the primary competition coming from Cascade Graphics. Within seven years the price for CADapple was just $395.

The initial T-Square software was written primarily by Mike Lazear. While in college he had done some work on drawing generation and serial drivers for peripheral devices that were incorporated into the Terak software. One of Mike Lazear's classmates at CSLB, Chris Stammen, was recruited to work on the Apple implementation of T&W's CAD software. Lazear describes Stammen as "one of the most intense, and good programmers I have ever met."[10] Paul Barr, who was Debbie Lazear's boyfriend at the time, joined the team on a part time basis along with several high school students, Brian Martin, Richard Endo and Ken van Hyning. They were bright young programmers who accomplished much while working for T&W. Martin went on to get a PhD in mechanical engineering from UCI and currently works on defense and aerospace programs such as the Predator drone.

Programming T&W's software for the Apple II was complicated by the fact that the computer being used by Chris Stammen had two floppy disk drive and no hard drive. The source code for CADapple filled 20 floppy disks. Each program compilation required that the disks had to be fed into the computer one at a time in sequence. If

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[8] Email from Tom Lazear, March 7, 2003
[9] *Anderson Report* April 1982
[10] Email from Tom Lazear, March 7, 2003

 

something went wrong, the entire process had to be restarted. According to Lazear, "He was the happiest man on the planet when we finally could afford to buy a 5 MB hard drive."[11]

Tom Lazear gives much of the credit for the quality of the CADapple and eventually VersaCAD software to Mike Lazear. Mike created the documentation methodology the company followed as well as the organization of the software code itself. According to Tom Lazear, "He brought in the new folks, trained them in the way we did things, parceled out the work, and carried the code up to over 1,000,000 lines of code that was originally in Pascal and then later in C…"[12]

**The VersaCAD era begins**

In November 1982, Autodesk introduced AutoCAD at COMDEX. Although no early comparisons have been found, it appears that CADapple had greater functionality than did AutoCAD at that point in time. T&W Systems soon had a PC version of its software. In January1983 the company introduced the T-Square software renamed VersaCAD for the PC, priced at $1,995. It used the UCSD-P operating system and essentially the same Pascal code that ran on the Terak system. The company also provided its software for rebranding by other system vendors including E2000 through Carrier Corporation for the Hewlett-Packard 9863, Terak MarsCAD through Staedtler Mars and OmniDRAFT through AT&T's OmniCAD Division. Staedtler Mars also resold VersaCAD on the HP9836 computer as MarsCAD. All these systems used the UCSD-P operating system.

In a paper presented at the 1983 NCGA Conference[13], Lazear described a typical Apple-based CAD system consisting of an Apple II computer with 64KB of main memory and a third-party floating-point card. Complete with a graphics monitor, two diskette drives, a plotter, a digitizer, and a comprehensive software package such as CADapple, these systems cost about $10,000 in 1983. At that price, a hard disc was not included. Lazear saw such systems being used as preprocessors to larger CAD systems or in situations where the expected productivity improvement did not justify a high-end system.

The balance of his 1983 paper went on to describe the functionality needed in a low-cost system. One important characteristic Lazear pointed out was that the user should always be working on a copy of the drawing, never on the original. The original would only be updated when the working copy was saved. This sounds like standard methodology today, but many systems of that era had users working on the saved copy of a drawing.

The early implementation of VersaCAD required an IBM-compatible PC with 128KB of main memory, two floppy disk drives, a monochrome monitor, a color monitor, two RS-232 serial ports, a digitizer and a pen plotter. The monochrome monitor was used for program messages and menus while the color monitor was used for graphics. Since VersaCAD drawings were stored in a floating-point format, a math co-processor was highly desirable.

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[11] Email from Tom Lazear, March 20, 2003
[12] Email from Tom Lazear, March 7, 2003
[13] NCGA *Proceedings* 1983 pg 492

 

Four PC CAD packages were profiled in the July 24, 1984 issue of *PC Magazine*: AutoCAD, VersaCAD, Drawing Processor (BG Graphic Systems), and CADplan (Personal CAD Systems). AutoCAD and VersaCAD were clearly seen by the author, Allen Meilach, as being the market leaders. AutoCAD was supported on more PC platforms than VersaCAD and took advantage of a wider range of peripheral devices. In particular, AutoCAD supported the use of a mouse for cursor control as well as tablets while VersaCAD required a tablet. AutoCAD also scored better in regards to the user's ability to customize menus, the creation of user defined cross-hatch patterns and nested graphical objects.

VersaCAD, on the other hand, was considerably faster than AutoCAD since it only had to scan active layers when it regenerated an image on the monitor. Other advantages VersaCAD possessed included the ability to dynamically track the size, position and orientation of symbols prior to placing them, the ability to place and edit fillets, the use of Bezier curves, and the use of a workfile concept for data recovery.

While a hard disk was not required, Meilach recommended one since this data recovery technique required frequent disk accesses. He also pointed out that although VersaCAD was more expensive than AutoCAD, it included many features that were optional with the latter program. Also, the VersaCAD buyer received free upgrades for the first year while AutoCAD users had to pay for them. Regarding VersaCAD, Meilach commented "The program is aggressively updated and should be a leading contender in the micro-CAD market."[14] By the end of 1984, T&W Systems had annual revenues of slightly over $2 million.

**VersaCAD is ported to MS-DOS**

By 1983, Microsoft's MS-DOS was clearly becoming the personal computer operating system of choice. An MS-DOS version of VersaCAD came out in 1984, or about two years late according to Lazear.[15] During the next six years, T&W Systems released a continuous stream of VersaCAD enhancements. A 3D surface geometry module with wireframe and hidden line removal for $495 was released in April 1985. According to *CAD/CIM Alert* "Incidentally, now that it is available for the IBM PC, T&W's VersaCAD may well rival AutoCAD's hold on the PC CAD market."[16] Since VersaCAD had been available on the PC since August, 1983, I am assuming that the newsletter was referring to the MS-DOS version of VersaCAD.

In October 1985, the company made a significant move when it introduced a UNIX version of VersaCAD for the Sun 2 workstation. As with many software packages of that period, the UNIX copy carried a price premium, $4,000 versus $1,995 on the PC. A Japanese language version of the package was also made available about the same time. This might well have been the first Japanese language version of a PC CAD package. The company also began to see large companies buying its software, utilizing its corporate site licensing agreement. For example, GE Aircraft Engine had over 3,000 active seats of VersaCAD at one time.[17] Other large users included defense contractor

[14] Meilach, Allen, "Getting the Picture", *PC Magazine*, July 24, 1984
[15] *Computer Graphics*, February 2001
[16] *CAD/CIM Alert*, April 1985
[17] *Anderson Report*, October 1985

 

AAI with 1,000 seats, AT&T with 1,000 seats and the California Department of Transportation with 300 seats.[18]

In December 1985, T&W Systems introduced VersaDATA, a relational database management system for the PC version of VersaCAD priced at $3,000. Then in March 1986, VersaMODEL, a solids modeling package licensed from Caetec Technology in Atlanta, Georgia was introduced with prices starting at $8,200. Shortly thereafter, the company extended its UNIX offering to include Apollo and IBM workstations. T&W Systems began to market EasyCAD in April 1986 priced at $495.[19] EasyCAD had been developed by Mike Riddle, the developer of the initial version of AutoCAD. EasyCAD was able to share files with both AutoCAD and VersaCAD.

The March 11, 1986 issue of *PC Magazine* contained an extensive article on PC CAD, its first since the previously mention 1984 article. This time it was written by contributing editor Glenn Hart and covered 11 different packages. Overall, Hart's comments regarding VersaCAD Advanced (the then current name for the 2D version of VersaCAD) were fairly positive. He liked the fact that the previous hardware protection which had required a plug-in card that took up an expansion slot in the PC had been replaced by a software technique called *SuperLok*. The software now supported the use of a mouse for cursor control and only a single monitor was needed. Menus appeared along the left side of the screen while messages and coordinate values were at the bottom.

Some of the other VersaCAD features Hart liked included:

- The use of single letter commands for frequently used actions.
- The ability to create temporary guidelines.
- The use of symbol outlines with internal detail suppressed to speed up display operations.
- The selection of symbols from individual libraries by entering the symbol number and library identification.
- The ability to calculate the area and perimeter of irregular areas as well as the ability to calculate cross section properties including moment, center of gravity, etc.
- The optional solids modeling module was considered superior to anything Autodesk currently offered but less functional than CADKEY.
- The optional bill of material module, VLIST, was considered to be particularly effective.

On the other side of the equation, there were a number of areas where Hart felt that VersaCAD needed to be improved. These included:

- The user interface, while "perfectly usable" was not up to the best of the competition.
- Dimensioning was considered limited – as an example, if a dimension did not fit, the user had to resize the dimension text.
- Drawings could only contain 100 different symbols.
- Crosshatching was still fairly limited with no predefined patterns and no ability for the user to define patterns.[20]

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[18] Email from Tom Lazear, March 20, 2003
[19] *CAD/CIM Alert*, April 1986
[20] "Complex CAD Software for the PC" by Glenn Hart *PC Magazine*, March 11, 1986

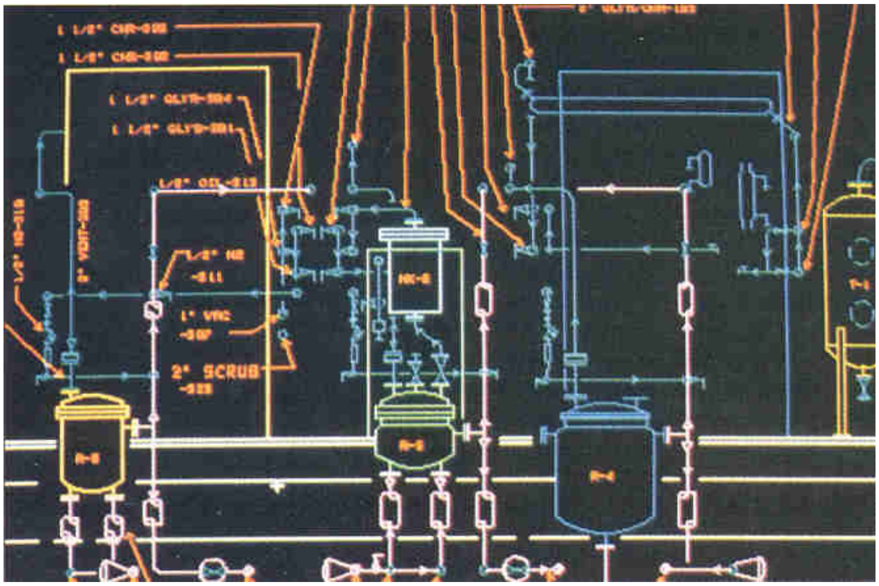


**Figure 20.2**
**VersaCAD Advanced Screen Image**[21]

## T&W and VersaCAD begin to mature

In 1986 T&W Systems changed its name to Versacad Corporation (Note different spelling of company name and product name). It had revenues of $5.5 million during the fiscal year which had ended July 31, 1986. According to Daratech Associates, the company had 30,000 users at the end of 1986 including 6,000 CADapple seats and 1,000 EasyCAD seats. By early 1987 the company's product line consisted of the following software packages:[22]

- VersaCAD Designer which included both VersaCAD 2-D and VersaCAD 3-D - $2,995 (The 2-D and 3-D modules now had a consistent user interface)
- VersaCAD 2-D - $2,495 (Earlier called VersaCAD Advanced)
- VersaCAD 3-D - $995 (This package required VersaCAD 2-D but was priced separately so that a user could start with 2-D and then move to 3-D)
- Expert Symbol Libraries - $495 each (symbol libraries were available for mechanical engineering, pipe fittings, heating, ventilation and air conditioning, industrial controls, hydraulic schematics, architectural, mapping, and electrical and electronic schematics)
- VersaData -$495
- VersaMODEL - $8,000 and up
- EasyCAD - $495
- CADAPPLE - $1,495
- CADAPPLE Entry Level - $99 (A limited function version of CADapple intended for education purposes)

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[21] "Complex CAD Software for the PC" by Glenn Hart *PC Magazine*, March 11, 1986
[22] *CAD/CAM CAE Survey, Review and Buyers' Guide*, Daratech Associates, 1987

Around this time, Versacad had slightly over 200 resellers around the world distributing its software including Tandy/Radio Shack, MicroAge and SPI SoftPac International. The company was one of the few in the CAD industry that sold corporate site licenses, a marketing strategy that it would resurrect in 1999. Versacad software was used extensively at educational institutions. The company claimed at the time that over 50,000 drafters were being trained annually at 1,300 educational institutions.

VersaCAD 2-D was particularly well suited for drafting architectural floor plans. The software handled multi-line walls with automatic corner cleanup as well as the ability to insert windows and doors into these walls. Most other CAD packages required a separately priced architectural add-on to handle these functions. This package also enabled users to automatically convert two dimensional drawings into isometric drawings. VersaCAD 3-D was a surface design package that handled a wide range of geometric primitives and produced shaded images or wireframe images with hidden lines removed.

VersaCAD Release 5.2 in early 1987 supported mass properties and automatic orthographic views. The company also introduced VersaCAD/Mechanical which contained a number of mechanical drafting enhancements including geometric tolerancing, priced at $495. In a press release that month, the company claimed that it had shipped 10,000 copies of VersaCAD 3-D during the prior five months.

A Macintosh version of VersaCAD became available in August 1987. According to Versacad, performance of VersaCAD on the Macintosh was about 2 to 2.5 times that of an IBM PC/AT and about the same as the new 80386 PCs. The major problem with this portion of the company's business was that Apple never did market its computers aggressively to the engineering community. Consequently, there was not much demand for Macintosh design software outside of the architectural area in spite of its ease-of-use characteristics which should have appealed to engineers. By mid-1987 Versacad had grown to 67 employees and had approximately $8 million in annual revenue.

**Prime acquires Versacad**

A significant change occurred in October 1987 when Prime Computer acquired Versacad for somewhat less than $6 million including $2 million up front and the balance based upon the subsequent performance of the VersaCAD product line. The intent was to continue the operation of Versacad as a separate business entity under the existing management. At the time, Prime had no other PC CAD business activity. Its primary CAD business was centered around Medusa which ran on the company's large minicomputers. Also in 1987, VersaCAD 5.3 was released with multiple 3D viewports.

In February 1988, Prime acquired Computervision, adding that company's Personal Designer PC CAD software to the corporate product mix. Lazear remembers this development being very disturbing to the Versacad employees.

> "….instead of being the only PC CAD part of Prime, we became one of two, and worse, we were general purpose doing $8 million per year and CV Personal CAD was targeting machine design software and doing about $25 million. Also, they were right next door in Bedford, MA while we

> were way out in California. We went from favored son to the 'other PC CAD in California.'"[23]

Then in January 1989, Prime completed the acquisition Calma. Lazear had spent nearly six months assisting corporate headquarters in arranging this deal. Bob Fischer was responsible for what Prime now called its Computervision Division in Bedford, MA and Lazear was a group vice president reporting to Fischer and responsible for Versacad, CV's Personal Designer and the Calma products. Overall, Lazear was responsible for about $100 million in revenue and 500 employees

Lazear, was quoted in a Dataquest study as predicting at NCGA '88 in Boston that PC operating systems would shift from MS/DOS and OS/2 to UNIX. The first was expected to decrease from 80% to 40% while UNIX on PCs increased from 0.7% to 30% and Macintosh would go from 18% to 30%. Lazear also predicted growth in the use of relational database management systems to support CAD applications and increased use of IGES. Artificial intelligence "is where the gold is."[24] He was quite accurate in regards to his observations on database management systems but severely underestimated Microsoft's eventual domination of the PC market.

By early 1989, there were 75,000 copies of VersaCAD in use. The price for the Macintosh version was $1,995 while VersaCAD Design for PCs and other platforms sold for $2,995. The software was considered by some to be easier to use than AutoCAD but the company's marketing efforts fell short of what Autodesk was doing.[25] During the next year just 5,000 additional copies were sold.[26] In fact, this 80,000 user figure was still being used in 1994 although Lazear believes that it peaked at about 100,000.[27] During this period, there were few significant product developments in regards to VersaCAD.

**Lazear leaves Prime Computer and forms Archway Systems**

Tom Lazear left Prime Computer in late 1989 to form Archway Systems, initially to provide a vehicle through which Lazear could provide consulting services back to the Computervision division of Prime. Mike Lazear left Computervision a year later and Archway became a reseller of CAD systems, first for Computervision products including VersaCAD and later for Bentley Systems. Today, Bentley products form the biggest portion of Archway's business followed by VersaCAD as described below.

In March 1991, Prime closed the VersaCAD facility in Huntington Beach, CA and consolidated its PC CAD operations in Bedford, MA. At this point in time, Computervision was selling three PC versions of VersaCAD: VersaCAD/386 designed to run in extended memory on 80386 or later PCs ($3,495), VersaCAD Design for pre-80386 machines (initially $2,995 but subsequently reduced to $1,995) and VersaCAD Drafter which supported limited 2D drafting ($595). The company also continued to sell a Macintosh version of VersaCAD for $2,995 as well as a UNIX version for Sun Microsystems systems.

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[23] Email from Tom Lazear, March 7, 2003
[24] *CAD/CIM Alert*, October 1988
[25] *CAD Rating Guide – First Edition*, 1989
[26] *Anderson Report*, February 1990.
[27] *CAD Rating Guide- Fourth Edition*, 1994

 

The February 23, 1993 issue of *PC Magazine* had a major article on 2D drafting solutions which was the last one I am aware of to include a detailed description of VersaCAD Version 7. This review was done by Rod Taylor. It doesn't appear that any major changes had been made to the software since the earlier *PC Magazine* review in 1986 although the software now incorporated Computervision's proprietary CAD programming language, CPL, and supported ANSI standard Y14.5M-1982 dimensioning and tolerencing. CPL was initially developed at Versacad in the mid-1980s by Paul Barr. It provided a library of routines that enabled a user to access the VersaCAD drawing file. As an example, one customer, Gary Miller, used it to create a program which automated the design of reinforced concrete parking structures.[28]

The software package now included a hidden line removal and shading module called QuickRender. Like most other PC systems, VersaCAD enabled the user to assign macro commands to tablet menus. VersaCAD Overlay, licensed from Image Systems Technology, enabled VersaCAD to read in raster images and use them as background images. Taylor particularly liked the fact that in a networked environment, a file currently in use could not be modified by another user.

The major complaint Taylor had concerning VersaCAD was the way the software managed memory. When the software was installed, the user was required to define the maximum workfile size. This determined the maximum number of entities in a drawing. Some drawing tasks such as cross hatching generated a large number of entities and could easily overflow this predefined limit. Selecting too high of a value on a machine with limited memory could restrict the software's ability to perform other operations.[29]

Once the PC CAD operation was moved back to Bedford, little attention was paid to the VersaCAD portion of the product line. As an example, at Computervision's annual user conference in September1993 there were ten papers presented involving Personal Designer but none from users or company personnel regarding VersaCAD.[30] By 1997, Computervision did not even feel it necessary to provide data on VersaCAD to the *CAD Rating Guide.*[31]

In 1992, the CAD software portion of Prime Computer had regained the Computervision name and it once again became a publicly traded company as described in Chapter 12. Computervision struggled throughout the balance of the 1990s to regain its former momentum without a great deal of success. Finally, in January 1998, Computervision was acquired by Parametric Technology Corporation which clearly was not interested in the VersaCAD product line. PTC had acquired Computervision primarily to get access to the latter company's large defense, aerospace, automotive and industrial equipment accounts. VersaCAD continued to languish, forgotten by all except its loyal users.

### Emerald Forest morphs Into Pelorus

One aspect of Prime's acquisition of Versacad that is not well known is the linkage between an advanced development project at Versacad called "Emerald Forest"

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[28] Email from Tom Lazear, March 20, 2003
[29] "2-D Drafting: Why Pay More" *PC Magazine*, February 23, 1993
[30] Fifteenth Annual Computervision User Conference Proceedings, September 1993
[31] *CAD Rating Guide- Fifth Edition*, 1997

and a subsequent technology initiative launched by Computervision several years later called "Pelorus." Emerald Forest started at Versacad in 1986 with the intention of applying two of the latest software development concepts, the use of object-oriented software technology and the combination of OS-2 and the Presentation Manager user interface. This was a substantial undertaking that was led by Chris Stammen. By mid-1987, Stammen and his development team had a prototype up and running.

In October 1987, Lazear and Stammen went to a major technology announcement hosted by Microsoft and IBM at the Gugenheim Art Museum in New York regarding the plans these two companies had for OS-2 and Presentation Manager V2.0. Versacad was one of 12 developers that had been invited to demonstrate software using these products. At the time, Microsoft and IBM were jointly involved in the development and promotion of OS-2 although the relationship was tenuous at best.

Lazear remembers Bill Gates and Steve Ballmer touring the tables where the invited developers were set up to show their new OS-2 software. When they got to the Versacad table, Ballmer introduced Lazear and Stammen to Gates who said "I've been meaning to ask, why do you CAD guys use floating point arithmetic?" Lazear says that he used as an example designing a large structure such as the Golden Gate Bridge to fairly fine tolerances using complex trigonometric calculations. He said that he clearly remembers the date since it was the Monday that the stock market crashed in 1987.

After Prime acquired VersaCAD in late 1987, Emerald Forest development continued at the company's Huntington Beach, CA office but no products explicitly based upon this technology were introduced as part of the VersaCAD product line. Eventually, the development of Emerald Forest was moved to Prime's Calma facility in San Diego, CA. Subsequent to the company being resurrected as Computervision this software was renamed Pelorus and marketed by the company as a new-generation CAD development environment. Computervision attempted to license the technology to other software companies as well as use it as the basis for the company's own applications. One such package introduced by Computervision was called DesignPost. It was intended to be the successor to VersaCAD but never made much of an impact in the market and eventually disappeared from sight.[32]

## Archway reacquires rights to VersaCAD

Archway Systems meanwhile had grown to be a respected reseller of both AEC and mechanical design software products. In particular, Archway was a significant reseller of Bentley Systems' MicroStation software in Southern California. In mid-1999 PTC notified VersaCAD users that as of a predefined future date, PTC would stop selling additional copies of VersaCAD and would only provide support for a short period thereafter. Lazear saw a business opportunity regarding VersaCAD and contacted some people he knew from his Prime/Computervision days. They put him touch with Steve Walske, PTC's CEO and after three months of legal wrangling they worked out a deal.

As of October 1999, Archway took over full responsibility for supporting VersaCAD and its installed base. Apparently, the only cost for doing this was an obligation by Archway to provide a VersaCAD to Pro/ENGINEER file converter. The first problem faced by Archway was contacting existing VersaCAD users. The only

[32] Email from Tom Lazear, March 20, 2003

mailing list available was nine years old. A mailing to that list, however, turned up 200 users with over 1,500 licenses in use.

Since reacquiring VersaCAD, Archway has reduced the price for a new license to $795 with an unlimited corporate license set at $5,495, ported the software to Windows, signed up numerous users to a maintenance and support plan, launched a new release of the Macintosh version and continued to enhance the overall package. Several of the original developers including Mike Lazear and Paul Barr are once again involved in supporting VersaCAD along with Mike's son Josh Lazear. Nothing like keeping it in the family for three generations.

Lazear believes that there are still 20,000 VersaCAD users and he intends to provide them the support he feels they deserve. A total of 600 organizations representing an estimated 6,000 seats of VersaCAD have signed up for Archway's software support program. The company continues to sell new VersaCAD licenses to schools, to existing users, to users who move to new companies, to companies looking for low cost CAD and to Macintosh users.

The Macintosh version of VersaCAD is an interesting situation. Although VersaCAD is one of only a few generalized CAD packages available for the Macintosh platform, the PC version outsells the Macintosh version ten to one. Fundamentally, Apple continues to do a poor job of marketing its computers to technical users. Complicating the Macintosh situation for Archway is that the new operating system of choice for that platform is OS X. Converting VersaCAD to UNIX-based OS X was a substantial undertaking, one that Archway completed in 2006.

**Why Did Autodesk Win this War**

The major issue surrounding VersaCAD is why Autodesk's AutoCAD package began to outsell it by a large margin within several years of the latter's launch in late 1982. VersaCAD was on the market first, was easy to use and had greater functionality during the early years of competition between the two products. There seems to be a number of reasons for Autodesk greater success.

- Once Mike Ford joined Autodesk, it became significantly more marketing oriented than Versacad, spending a substantially greater portion of its capital on marketing. One example provided by Lazear involved an early A/E/C SYSTEMS conference in Anaheim, CA. Ford sent free airline tickets to a number of speakers prior to the show inviting them to visit Autodesk in Sausalito, CA. As a consequence "every speaker talked about what they had seen at Autodesk."[33]
- Autodesk built a larger reseller channel and did so faster than Versacad.
- Autodesk was more proactive in supporting 3rd party developers and user groups.
- Several industry analysts feel that the fact that VersaCAD utilized hardware protection for its software while Autodesk did not except for a brief period of time, was a significant factor in Autodesk's relative success.[34] Lazear agrees that the company's own market research confirmed this perception. When T&W Systems dropped all hardware

[33] Email from Tom Lazear, March 7, 2003
[34] Personal conversation with Dr. Joel Orr, February 28, 2003

 

protection in 1985, the company did not see a significant improvement in sales based upon this action, however.[35] My conclusion is that hardware protection may have been a contributing factor to Autodesk's relative success but was not a dominating factor.

- Autodesk supported MS-DOS from the start while it took some time for VersaCAD to be ported from UCSD-P to MS-DOS. T&W Systems selected UCSD-P over MS-DOS because it felt that the former operating system was technically superior to the Microsoft product. Current readers may not be aware that there were perhaps as many as ten different operating systems to choose from during the early days of the PC. Lazear was not impressed by the early versions of MS-DOS. "I remember evaluating it in 1980 and saying 'this is trash' very inefficient and awkward. It didn't have all the features or support that UCSD-P had."[36]
- Autodesk gave away a large number of licenses to educational institutions while T&W Systems continued to sell software into this market. According to Lazear, "We were reluctant to give away the badly needed revenue."[37]
- VersaCAD was priced at $1,995 and then $2,995 at a time when basic AutoCAD was being sold for $1,000.

[35] Email from Tom Lazear, March 7, 2003
[36] Ibid
[37] Ibid

# Chapter 21

# Miscellaneous Companies

Space restrictions simply do not permit me to go into the depth of detail I would like on every company that participated in the early days of the CAD industry nor cover numerous in-house systems developed at major automobile and aerospace companies. Readers will have to be satisfied with the brief descriptions included in this chapter and even then, I have only been able to cover what I consider to be the companies that had the biggest impact. There are hundreds if not thousands of companies that at one time marketed engineering design software. Some of the companies described in this chapter offered just software while other provided both hardware and software. While many have changed names, I have decided to list them alphabetically based upon the name they are best been known by along with earlier and subsequent name changes.

**Adra Systems (Matrix One)**

Adra Systems was founded in Lowell, Massachusetts in July 1983 by William Mason, who had been at Applicon from 1973 to 1983, most recently as vice president of operations, James Stenzel, who had been vice president of engineering at Hastech, Inc., and Peter Stoupas, who had earlier been a regional sales manager at Adage and had also worked for Applicon. Mason became the president and CEO, Stenzel the vice president of product development and Stoupas the vice president of marketing. Between 1983 and 1986, the company raised $11.6 million of venture funding from a number of firms including American Research & Development, the company that also provided the initial funding for Digital Equipment Corporation.

Adra's initial product, introduced in January 1985, was a CADAM-compatible combination of hardware and software that was marketed by Adage, Inc as the CADStation 2/50. At the time, Adage was one of the major non-IBM manufacturers of graphic terminals used to support the mainframe CADAM software sold by IBM. The software component, which was called Cadra-1, emulated the look and feel of CADAM. It could extract a drawing from a mainframe database, work on the drawing and then re-file it on the mainframe.

CADAM, Inc. did not take kindly to this product introduction since it competed directly with the sale of CADAM. A lawsuit was filed against both Adage and Adra which settled out of court in 1987. CADAM, Inc. received a payment "in excess of one million dollars" and Adage agreed to no longer sell the CADStation 2/50 once its existing inventory was depleted.[1]

The company introduced the Adra 1000 system in November 1985. Similar to the CADStation 2/50, it consisted of a 10-MHz Motorola 68010 microprocessor with 2.5MB of main memory, UNIX, a custom graphics processor and a 19-inch 1024x1024 monochromatic or color monitor. No local hard disk was provided. Graphics performance, particularly pan and zoom operations, was very fast. The major difference from the earlier system was that the Adra 1000 with its Cadra-2 software was intended to

[1] *Computer Aided Design Report*, November 1987, Pg. 14

be used as a standalone two-dimensional drafting system. The initial price for a basic system was $15,750.

A year later, Adra Systems introduced the Adra 3000, similar to the 1000 except with a Motorola 68020 microprocessor, a higher performance graphics accelerator, better communication capabilities and an optional 20MB disk drive. With the company's Cadra-2 software, the Adra 3000 could be used as an adjunct to a CADAM system or as a low-cost alternative. These systems started at $14,750 for the monochromatic version and $18,750 for the color system. Meanwhile, the price of the Adra 1000 was dropped to $11,750.

In August 1988, Adra introduced a PC-based system called Acclaim. The key element was an external co-processor that included the company's bit-sliced graphics processor and 4MB of memory. The Cadra software actually ran in this co-processor which plugged into one of the PC's parallel ports. The software and co-processor sold for $10, 795 while a complete system including a 16-MHz 386 PC and 19-inch monitor was priced at $21,190.

Eventually, Adra got out of the hardware end of the business and concentrated on the Cadra software. It positioned itself as providing a low-cost alternative to the large enterprise-type systems sold by Computervision, IBM Applicon, etc. The company stressed Cadra's ease of use and the user's ability to customize the software using a programming tool called "Autogeometry." This latter software was also used to interface Cadra to systems other than CADAM. Both PCs and UNIX workstations were supported.

By 1996, the company had installed about 17,000 copies of its software at 1,500 to 1,600 customers. Adra offered a number of different packages at this point. Cadra Design Drafting was the company's flagship product. Selling for $3,995, it was no longer simply a CADAM clone. Adra had added many of its own concepts including intelligent dimensioning, variational and parametric editing, unlimited drawing size (this was one of the major limitations of CADAM), display of up to 200 views and license management that allowed copies of the software to be shared over a local network.

The software was available on most UNIX platforms as well as on Windows. To make the transition to Windows less painful for existing users, the company left the older user interface in the software and the user could select either the Windows paradigm or the older interface.

Adra also developed a solids modeling package, Cadra Solids, based on the DesignBase geometric kernel from Ricoh Corporation. This was a hybrid modeler that allowed users to mix wireframe, surface and solid geometry. While other low-cost packages tended to use faceted surface geometry, Cadra Solids used precise B-REP techniques. Editing was done by grabbing a vertex, edge or surface with a mouse click and dragging it to a new location. The user could also directly modify a model by editing its history tree. Initially, Cadra Solids, which was only available on UNIX workstations, sold for $5,995, the same as the UNIX version of the basic Cadra package. Combined, the two packages cost $10,995. Several years later this price was down to $6,500 which was still nearly twice what SolidWorks sold for at the time. Adra also offered NC software as well as a package for electrical control and power system.

In 1992, Adra established a new operation in Shelton, Connecticut to develop product data management (PDM) software. This group, initially called the "Looking Glass Project" and subsequently the Matrix Division, was headed by Joseph Pieto who had previously developed IGOR[2], a document management package, at the Sikorsky Division of United Technology. The company introduced this software as a PDM product called Matrix. It used a relatively new object-oriented database, Objectivity DB from Objectivity, Inc. The system had impressive capabilities but like many other early object-oriented systems, suffered performance issues when it was scaled up to handle a large volume of data.

Like Cadra, Matrix had an easy-to-use user interface, good document routing capabilities, a distributed database that eliminated the need for a centralized server and the ability to manage a wide range of documents. Mark O'Connell joined Adra as vice president of marketing in 1995. He had previously held a series of financial and marketing management jobs at Digital Equipment Corporation. O'Connell became president of Adra in 1996 and CEO in 1997.

Within a few years, the tail began to wag the dog. In an interview in 1996, Mason stated that the portion of the company's business represented by Matrix had gone from 15 percent in 1995 to 33 percent in 1996 and would be 50 percent in 1997. Eventually, he thought it would become 80 percent of Adra's business.[3] It actually became 100 percent in 1998 when in May of that year Adra sold the design and manufacturing software portion of Adra Systems to SofTech for $11.4 million. At the time the Cadra product line was generating about $15 million in annual revenues while Matrix was responsible for $21 million..

The company used these funds to shift its PDM business into high gear. It changed its name to MatrixOne and the product became eMatrix to reflect its Internet focus. Sales increased to nearly $75 million in fiscal 2000 (the company's fiscal year ended July 1) and the company went public on March 6, 2000, selling 6.2 million shares at $25 per share. Almost immediately, the price increased to over $70.

The next year revenues nearly doubled to $145 million, resulting in profits of $8.8 million. This was the company's peak year. Revenue dropped over the next several years to $109 million in fiscal 2003 and 2004 and the company incurred substantial losses before heading back into the black in late 2004. By October 2002, the company's stock had lost over 95 percent of its value from its earlier high and only improved moderately over the next few years. On March 2, 2006, Dassault Systèmes announced that it was acquiring MatrixOne for $7.25 per share (approximately $408 million) or about 3.3 times revenue. The acquisition was completed on May 11, 2006 and MatrixOne became ENOVIA MatrixOne.

### Alibre

Alibre was founded in Richardson, Texas in 1997 by J. Paul Grayson and Stephen Emmons. The company was initially called Entity Systems but changed its name to Alibre before any software was shown to the public. Grayson was the founder and former CEO of Micrografx, a vendor of low-cost PC graphics software including PC-Draw. Emmons was also formerly at Micrografix where he was the principal developer of Micrografix Designer. Grayson, who put up the initial funding for Alibre, was the CEO and Emmons chief technology officer. Over the next several years the company raised over $18 million in venture funding.

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[2] Named after Igor Sikorsky, the founder of Sikorsky Aircraft
[3] *Engineering Automation Report*, March 1996, Pg. 6

During its first two years the company concentrated on developing a new mechanical design package that could be provided to users over the Internet. The delivery mechanism was referred to as an Application Service Provider or ASP. Users would access the software with nothing more than a web browser on their desktop or notebook computer. The actual application software resided on servers operated by Alibre.

The software, Alibre Design, was first shown publicly at the M/TECH '99 conference in Chicago in November 1999. It used Spatial Technology's ACIS kernel, D-Cube's constraint manager as well as component software from several other providers. *Engineering Automation Report* was fairly enthusiastic, probably overly so, about this new concept for providing CAD software:

> "Just when you figure that the mechanical CAD industry has more software vendors than it can rationally support, along comes a new company with new ideas that forces you to realize that there really is room for another vendor…... Since the software runs on servers managed by Alibre, there is no need to invest in expensive computer hardware. In addition, if a designer is visiting a supplier, he or she can log on to the service from any available computer. No need to have the design software locally loaded. Within a few years, you might be able to work on designs from your seat on an airplane. ……..The design software that we viewed seems to be comparable to the early stages of most other mid-range solutions……. We have a gut feeling that this company is going to make it big. It is well financed and appears to have a strategy right on target. Many computer industry observers, including this newsletter, believe that ASPs are the wave of the future." [4]

The software as provided in a "preview version" a few months later differed somewhat from what had been presented at M/TECH. In addition to the pure ASP implementation described above, the company offered a version where the model creation and editing software was moved to the user's desktop system and the ASP server was used to store and manage the user's data. Initial performance was relatively slow, probably because the software was written in Java which still executed interpretively rather than in compiled mode. The software turned out to lack some of the capabilities users had come to associate with most mid-range packages such as variable radius fillets and free-form surfaces. In a significant change of focus, the company began shifting its marketing message from pure mechanical design to design collaboration.

Alibre Design 1.0 went live on April 10, 2000. It was made available on a subscription basis at $100 per month per user or on a self hosted basis at a price of $5,000 for six months use. Virtually all of the company's sales and support activities were web based. Meanwhile the company's management team was growing rapidly. Tommy Steele, who had previously been president of Intergraph Software Solutions, was COO, Tom Kopinski, who had been with Autodesk and SolidWorks, was vice president of sales and Greg Milliken, who had been with Knowledge Revolution before it was acquired by MSC.Software, was vice president of marketing. Neither Steele nor Kopinski stayed long but Milliken eventually became president and CEO of the company.

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[4] *Engineering Automation Report*, December 1999, Pg. 7

 

Grayson and company were strong believers in Microsoft technology and Alibre was one of the first applications to support Windows 2000. In fact, Bill Gates used it as a demonstration tool for the Windows 2000 launch.

Alibre evolved into a four-tier product:

1. A web browser-based client that handled the display and manipulation of wireframe and shaded models.
2. An application design server that supported model creation and editing as well as drawing production.
3. A database server the handled access privileges, revision control and check in/out. This was often referred to as the repository server.
4. An administration server that tied this all together.

The separation of the browser-based client from the design and data management servers allowed the client to run locally while the design and data management services could be either local or remote. By October 2000, Alibre had changed its business model and was providing the modeler as a free 18MB download and charging for the collaboration services it was providing on a subscription basis. About the same time it released Alibre Design 2.0 which addressed some of the performance issues.

Alibre got off to a slower start than expected. Although thousands of potential customer downloaded free trial software, less than 1,000 signed up for the company's subscription service as of February 2001. Those that were using it were probably more intrigued by the software's collaboration capabilities than by its design prowess which lagged competitive packages such as SolidWorks. About this time, Microsoft and Sun Microsystems settled their dispute over Java and Microsoft introduced a new programming language, C# as its web-centric programming language of the future and Alibre stated that it would convert from Java to C# in the future.

With Alibre Design 4.0, released in May 2002, the software became a Windows application rather than being browser based. The software could be used either off-line or in a collaboration mode over the Internet.

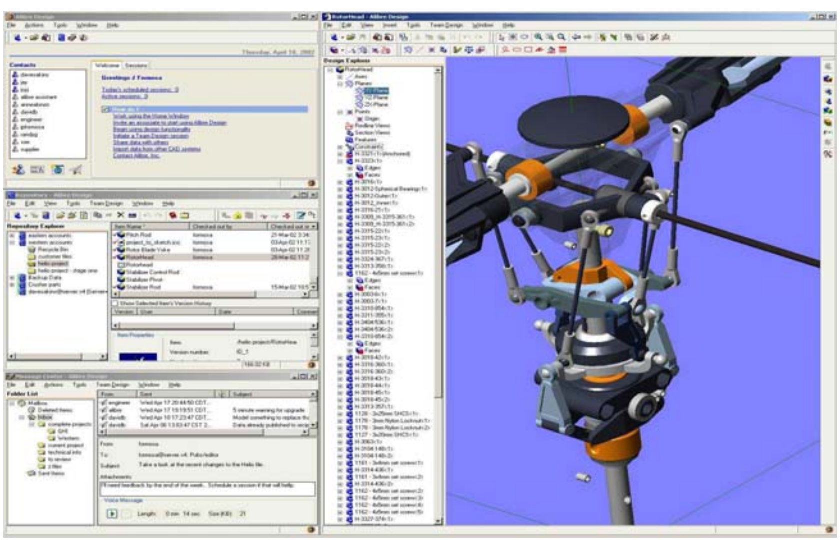

Figure 21.1
Alibre collaboration software

The company’s business model changed once again with the $100 monthly subscription fee dropped and replaced by a $995 annual fee. Then a $495 promotion, which was offered when 4.0 was released, soon became the new price point. Self-hosted licenses were also available at prices based on the number of users. By 2002, however, the company was no longer aggressively pushing this type of business. The software was provided either on a CD-ROM or as a 25MB download. Increasingly, the company emphasized its collaboration capabilities and the ability to work with data from other CAD systems.

In late 2002, the company’s focus changed once again and Alibre began promoting its software as a low-cost alternative to competitive mid-range packages. An enhanced version of the software, Alibre Design Professional, was released in April 2003, priced at $995 for an annual license, while the basic version of the software was increased to $695 per year.

One of the more interesting aspects of the Alibre story was the outright theft of its software by a Russian programmer, Roman Voznyuk, who had been laid off in 2003 during a corporate reorganization. Voznyuk returned to Russia and began offering a slightly modified version of Alibre Design as RaceCAD Design Professional. Alibre filed lawsuits in both Russian and American courts claiming that RaceCAD was created directly from source code for Alibre Design, and that RaceCAD also incorporated software stolen from Spatial, D-Cubed, the OpenDWG Alliance, and others. Criminal charges were also filed.

According to Grayson: “he offered to 'settle' with us and discontinue the English version if we gave him the Russian version. Clearly, the only thing he is going to get is a stiff penalty and likely jail time.”[5] While the lawsuits were never resolved, RaceCAD simply faded from the scene. Then in August 2007, Voznyuk was arrested in upstate New York as he attempted to enter the United States from Canada where he had been working.

In February 2004, Milliken became president and CEO while Grayson remained chairman of the board. One of Milliken’s first steps was to raise the price of the company’s products to $795 annually for Alibre Design, $1,295 for Alibre Design Professional, and $1,795 for Alibre Design Expert, a newer more expanded version of the software. A free stripped down version, Alibre Design Xpress was launched in mid-2004. Xpress drew large numbers of prospective users to the company’s web site and a significant number ended up as paying customers for Alibre Design.

Alibre never became the $100 million business Grayson expected, but it did become a profitable business. It continues to be an interesting chapter in the evolution of the CAD industry. As this is written, the company’s software is being sold by VARs as well as on-line although the on-line approach is the company’s preferred sales and support vehicle. Its board of directors include individuals such as Jeremy Jaech, the founder of Visio and Mike Maples, a former executive vice president of Microsoft.

**Aries Technology**

Aries Technology was organized in Lowell, Massachusetts in November 1984 by Larry McArthur, Richard Miller and several other ex-Applicon and Computervision managers including Gerald Christopher, Peter Pritchard, Dr. Jack Horgan, Arthur

[5] http://www.castlecops.com/article3793.html

 

McCray and Jerry Sabath. McArthur was the only one who had not previously worked for one of the early CAD vendors. He had been president and general manager of Gould's Measurement Systems Division.

McArthur was Aries' president and CEO, Miller headed up marketing, Christopher finance, Pritchard sales, Horgan product development McCray software development and Sabath hardware development. The company raised $22.5 million in venture funding over the next three years including an investment from Eastech Limited Partners, one of whose principals was Fontaine Richardson, a founder and former vice president of Applicon.

The company's objective was to provide software that could be used during the conceptual phase of product design. The term they used to describe this process was "predictive engineering." Two years after being founded, Aries introduced its first product, the IBM PC AT-based Aries ConceptStation, at AUTOFACT '86 in Detroit. Both bundled (AT200) and unbundled (AT1200) versions were sold with prices starting at $32,000 for the unbundled version and $49,900 for a bundled configuration. The early ConceptStation systems required a Aries-built Graphics Engine in order to achieve reasonable interactive performance on the PC AT.

In an attempt to provide an "open system" Aries selected Microsoft's Xenix implementation of UNIX as its PC operating system. The early Aries' application software included a precise solids modeler, kinematics analysis and finite element modeling as well as other analysis software. A Design Rule Processor enabled engineers to tailor this process to incorporate the design steps most applicable to the product being worked on. A lower cost version of the ConceptStation, the AT1100, was introduced a few months later with prices starting at $21,850.

Over the next few years, Aries developed partnerships with a number of other software firms including Swanson Analysis Systems, Mechanical Dynamics Incorporated, MacNeal-Schwendler Corporation (MSC) and Autodesk. As a result of these relationships, Aries began to include subsets of analysis programs such as Swanson's ANSYS and MDI's ADAMS in its ConceptStation software. The company also began to support most commonly available UNIX workstations as well as Intel-based PCs. As the hardware performance increased, the need for a custom graphics accelerator decreased and Aries ceased manufacturing its proprietary Graphics Engine.

In August 1989, Aries signed an agreement with Ford Motor Company under which Ford invested $6 million in the company and agreed to purchase an unspecified amount of Aries software products. This turned out to be an important relationship in that Ford had previously established a major technology project, Alpha Simultaneous Engineering. This was a 450-person organization under the leadership of Dr. Howard Crabb[6] whose mission was to develop improved products and processes that could be transferred to the rest of the company. Much of their efforts centered around the use of ConceptStation as the conceptual design tool that could help the company significantly reduce design time as well as create better products.

A major product change occurred in November 1991 when Aries announced that it would incorporate the ACIS solids modeling kernel in the ConceptStation, replacing its proprietary modeler. This turned out to be a problematic decision in that ACIS in 1991

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[6] Crabb is the author of *The Virtual Engineer – 21st Century Product Development*, published in 1998

 

was not ready for prime time. At this point in time, ConceptStation consisted of about a dozen software modules including:

- ConceptSolids (ACIS-based solids modeler)
- ConceptParametrics (parametric design)
- ConceptFEM (finite element modeling with automatic mesh generation and post processing)
- ConceptFEA (a subset of the ANSYS analysis package
- ConceptCompose (drawing production)
- ConceptDraw (drawing dimensioning).

In July 1992, Aries signed a significant joint development and marketing agreement with MSC. A few months later, Miller was made executive vice president and chief operating officer of Aries. A number of new products were introduced that linked Aries and MSC software together more tightly than before.

The next big change occurred in September 1993 when Aries was acquired by MSC and became the MSC/Aries division of that company. McArthur moved to Los Angeles and assumed the title of chief operating officer for MSC and Miller continued to run the Aries division in Lowell. McArthur left MSC after about a year and worked for a period of time at SGI as director in mechanical industry marketing. Later, he became president and CEO of Saxonyx, a company that developed information management software for the drug industry. Miller stayed for another year before leaving to become an industry consultant.

The company's plan was to position MSC/Aries primarily as a graphic pre- and pos-processor for MSC's analysis software. This concept changed after MSC acquired PDA Engineering about a year later. PDA's PATRAN software for pre- and post-processing FEA models was substantially more mature and had a larger installed base than did the Aries software. As a result, PATRAN became the more heavily promoted package and MSC/Aries faded into the background although some customers were still using it six or eight years later.

**Ashlar**

Ashlar was founded by Dr. Martin Newell in 1988 after he left Cadlinc, another company he help start in 1981 as described below. Newell had also worked at the CAD Center in Cambridge, England and then at the Xerox Palo Alto Research Center (PARC). He was well recognized as one of the industry's leading authorities on graphical user interfaces. Other ex-Cadlinc managers who were involved in Ashlar included Grant Munsey and Dan Fitzpatrick. Ashlar was funded in part by Hambrecht and Quist which had high expectations for this new startup. Bill Hambrecht, the head of Hambrecht and Quist sat on Ashlar's board of directors for a number of years.

The company's initial product, Ashlar Vellum, was significant predominately because of the package's user interface. Newell's intent was to create a design package where the interaction between the user and the software flowed in a natural rhythm. The focal point of the Vellum software was patented technology the company called the Geometric Inference Engine. This software formed the basis for Vellum's user interface which was referred to as the Drafting Assistant. It used a technique called a "Smart Cursor" to speed user interaction by inferring what the user might want to do next. As an example, if the user placed one end of a line near a circle, the logical next step might be to make the line tangent to the circle. If the user had a different intention, this operation could easily be overridden.

Initial versions of Vellum were implemented on the Apple Macintosh computer with a Windows PC version following in the early 1990s. Unfortunately, Apple owned a software group at the time called Claris which also sold a two-dimensional drafting package called Claris CAD. Therefore, it was not particularly interested in helping to promote the Ashlar software.

The first released version of Vellum handled two-dimensional design. It was followed in early 1992 by Vellum 3D, initially for the Macintosh and later that year in a Windows version. This new software soon became the company's primary focus. Vellum 3D extended the Drafting Assistant into the Z dimension, enabling users to create graphics on the equivalent of a three dimensional isometric grid. Ashlar also added a graphical trackball display. By rotating the trackball with a graphic cursor, the user could rotate the model being worked on in any combination of the three axes.

The major drawback of the software in the early 1992 time frame was the lack of any surface or solid geometry capabilities. Hidden lines had to be removed manually at a time when most competitive systems did it automatically. In addition, there was limited capability to create assemblies. The two-dimensional version of Vellum sold for $1,995[7] while the three-dimensional version was $2,495[8]. In the first three years, Ashlar sold about 5,000 copies of Vellum. Then in August 1993, the Claris Corporation subsidiary of Apple withdrew Claris CAD from the market and recommended that its customers purchase a low-cost upgrade to Vellum. This move provided Ashlar with several thousand new users.

During the company's early years, Newell was both the company's chairman and chief technology officer while day to day operations were run by Jack Hendren, the company's president and CEO. Hendren had earlier been with CADAM, Inc. where he led that company's EDA business unit.. In November 1994, Frank Puhl, the former president of CADAM, Inc. joined Ashlar's board of directors.

By the mid-1990s, Vellum was a well respected product but one that still did not have a lot of market traction. Some users, including Burt Rutan, the designer of advanced aircraft at Scaled Composites including the recent Space Ship One, were enthusiastic about the software's capabilities as a conceptual design tool. Ashlar simply could not match the marketing clout of Autodesk and as a result the company became a niche player in the industry.

Vellum 3D Version 3.0, introduced in 1996, boosted Ashlar into a new realm of design tools with NURBS surfaces, shading, hidden line removal, and interfaces to higher-end solid modeling products offered by other vendors. Ashlar was still a fairly small company with about 20 employees at its Sunnyvale, California headquarters and another 12 in Japan. There were also three to four people at CADSoft Solutions in Dallas, TX who were helping develop ACIS-based Vellum Solids, which was released in early 1998. It was priced at $4,995 when combined with Vellum 3D. The company, by then, was basically being run by Nathan (Nat) Natarajan, its executive vice president, who had joined the company in 1993 from Autodesk.

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[7] The Apple version of Vellum was initially price at $995 and was sold through software stores rather than by dealers.

[8] *Computer Aided Design Report*, January 1992, Pg.12

In 1994, Ashlar filed patent infringement suits against Structural Dynamics Research Corp. (SDRC) and Diehl Graphsoft. The suits alleged that the graphical user interfaces used in their respective products, I-DEAS Master Series and MiniCAD, violated a pair of patents held by Ashlar related to the Geometric Inference Engine and interactive drawing system technologies. Ashlar contended that the SDRC's "Dynamic Navigator" found in I-DEAS Master Series and Diehl Graphsoft's "SmartCursor" found in MiniCAD made inappropriate use of its technology. Ashlar had negotiated licensing agreements with a number of other companies regarding use of this technology.

SDRC eventually won this case when the patents in question were ruled invalid although the case dragged on for years as Ashlar repeatedly appealed court verdicts.

In 2000 Ashlar moved its operations to Austin, Texas and new versions of the Vellum software were periodically released for both the Macintosh and Windows platforms. Robert Bou became president and then in early 2005, the company was acquired by Vellum Investment Partners which consisted of Bou and his wife Julie. This was followed by the opening of a software development office in Kiev, Ukraine.

While the company name is still Ashlar Corporation, it tends to use the term Ashlar-Vellum when it describes itself. Ashlar's products consist of Graphite ($995) for two dimensional drafting and Argon ($995), Xenon ($2,995) and Cobalt ($3,995) for three dimension design where the latter two incorporate solids modeling. Ashlar's licensing agreement allows a user to install the software on multiple machines (i.e. a PC at work and a Apple computer at home) as long as only one license is being used at a time. For users who need the software for short periods of time, the company offers annual and monthly licensing agreements.

**Automation Technology Products (CIMPLEX Corporation, Technology Answers)**

Automation Technology Products (ATP) was started in April 1983 by Robert Benders, the former president and CEO of Calma, John Benbow, vice president of product development at Calma and Lem Bishop, the chief financial officer at Calma.. Between 1983 and 1987, the company raised a substantial amount of venture funding from investors including The Mayfield Fund, Arthur Rock and Hambrecht & Quist. Benders was CEO of the new company, Benbow was senior vice president, technology and Bishop was vice president of finance and administration.

ATP's plan was to develop a comprehensive design, analysis and manufacturing system based on parametric solids modeling that ran on IBM mainframe computers, initially using that company's VM operating systems and 5080 graphics terminals. The company's software was also one of the first products to incorporate the concept of feature-based design and manufacturing. Rather than developing this software in a vacuum, the company signed technical cooperation agreements with Ingersoll Milling Machine Company and the Vought Aero Products Division of LTV Corporation.

The software product was called CIMPLEX and it consisted of feature-based solids modeling, analysis, manufacturing and data management modules. The CIMPLEX software enabled the user to work with three-dimensional shaded and edge-highlighted solid models as well as with wireframe and hidden line removed images.

In retrospect, selecting IBM mainframes for the software's primary platform may well have been a fatal mistake in that UNIX workstations were starting to make a significant impact on technical computing. At the time, ATP was led to believe that IBM was planning to introduce a VM workstation much as Digital eventually introduced VMS workstations. At IBM, it just never happened. The IBM mainframe decision was further complicated when prospects pushed the company into porting the software to the MVS/XA operating system. This turned out to be a substantial task and for a time involved a third of the company's R&D staff. Selecting PL/1 as the programming language also turned out to be a problem as it did at Applicon.

For the most part, ATP developed the entire CIMPLEX suite of software rather than licensing external components. This was probably an additional contributing factor to the company's eventual downfall. Developing solid modeling, finite element modeling, manufacturing and data exchange software would have filled any company's plate. But in support of these applications, the company also wrote its own database program, rewrote IBM's disk handling routines and created its own VM and MVS command language. CIMPLEX was fairly expensive software. The mainframe version of the basic design module was priced at $100,000 while the entire suite was $350,000.[9]

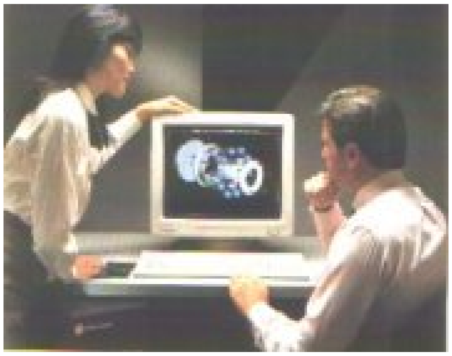

Figure 21.2
ATP CIMPLEX Workstation (Get original image)

Ralph Ezard, who was working for ICL in England, was recruited by Benbow in 1984 to run the company's consulting services business and Jay Orlando, previously with Computervision, was hired as vice president of sales. Peter Marks, formerly with SDRC where he was general manager of product planning and marketing, joined ATP in February 1985 as vice president of product planning and marketing. The company closed its first sale to Ingersoll in late 1985. Over the next several years its customers included Northrop, Sikorsky Aircraft, Boeing and Chrysler Corporation. As with earlier technical partners, these companies also worked closely with ATP in defining and testing the company's software.

Benders resigned as CEO in June 1986 and subsequently became president and CEO of Megatek Corporation, a vendor of high performance graphics terminals owned by United Technologies, the same company that once owned Calma. Benders was replaced a few months later by Dr. Russell Henke, the president and general manager of Gould Incorporated's Imaging and Graphics Division. Henke had earlier been executive vice president of Applicon and president and COO at SDRC. (see chapters 7 and 17).

[9] *Daratech CAD/CAM CAE Survey, Review and Buyers Guide*, 1987, Daratech Associates

A major task facing the company was porting the CIMPLEX software to UNIX. This was done in two steps. First, the software was modified to support Silicon Graphics workstations as an alternative to the IBM 5080. SGI produced a PL/1 compiler for its workstation systems that enabled ATP to port the full suite of CIMPLEX software to run in native mode on SGI workstations.

In 1987, Henke negotiated a $5 million investment in ATP by Chrysler for a 10 percent interest in the company. It was too little, too late, however. The company continued to struggle for the next two years before it finally filed for Chapter 11 bankruptcy in the latter part of 1989. By then, investors had poured a total of nearly $36 million into the company with very little return on their investment. One result of the bankruptcy proceedings was that ownership of the CIMPLEX software was transferred to a new company, CIMPLEX Corporation, which was financed by a $1 million investment from Morgan Stanley. The new CEO was Ted Sarbin who was new to the CAD industry.

For the next 15 years development of the CIMPLEX automated manufacturing software continued although at a somewhat reduced rate of investment. From 1990 until 1998 the company's president and CEO was Jerry Robertson. Up through at least 1996, this software was referred to as Manufacturing Analyst. CIMdata felt that the company had some of the leading software for what is referred to as generative machining but that CIMPLEX never seemed to be able to become a significant factor in the NC industry.[10] The company also developed some effective NC verification software under the direction of Peter Atherton.

In 1998 the CIMPLEX technology was acquired by Technology Answers, Inc. and the software was renamed Cimskil. The current version of the Cimskil allows a user to import a CAD model and using data describing the organization's NC machine capabilities, automatically generate optimized tool paths. The software does this by recognizing model features such as slots, bosses, pockets, etc and selecting the best tool and machining method for that feature. Users can override any aspect of the automatically generated tool path and insert their own tool selection and procedures.

An article in the April 2002 issue of *Modern Machine Shop* described one project where Cimskil was used to program a 5-axis machine tool for a set of parts that had previous been done on 3- and 4-axis machines. The results were impressive. Working with Cimskil, the part programming took from a third to a tenth of the time compared to conventional NC part programming and production time was also a half or less of the previously recorded time.[11] Much of the software development was done under contract to the U.S. Department of Defense which was interested in being able to rapidly produce aircraft spare parts.

**BruningCAD**

Bruning was a division of AM International that sold engineering supplies and reproduction equipment. In April 1981 it began selling a low-cost drafting system called Easydraf[2] that was based on two-dimensional drafting software licensed from Graphcon. A complete system, which sold for $69,500, included a Hewlett-Packard 9845B desktop

[10] Christman, Alan, *NC Software Buyer's Guide, 4th Edition*, CIMdata, November 1996
[11] Zelinski, Peter, "Empowering the Programmer", *Modern Machine Shop*, April 2002

 

computer with a 13-inch raster display.[12] This was subsequently replaced by HP 9000 Series 200 computers with either a 9-inch or 12-inch color display.

Graphcon was started in 1977 by Livingston Daniels in Tulsa, Oklahoma. Its Easydraf software was available on Tektronix 4050 graphic systems as well as the HP 9800 series. AM International acquired Graphcon in July 1983 and Daniels became president and CEO of the renamed BruningCAD. In September 1983, Lou Epstein who had previously been with Tektronix and Intergraph, joined as vice president of sales and marketing.

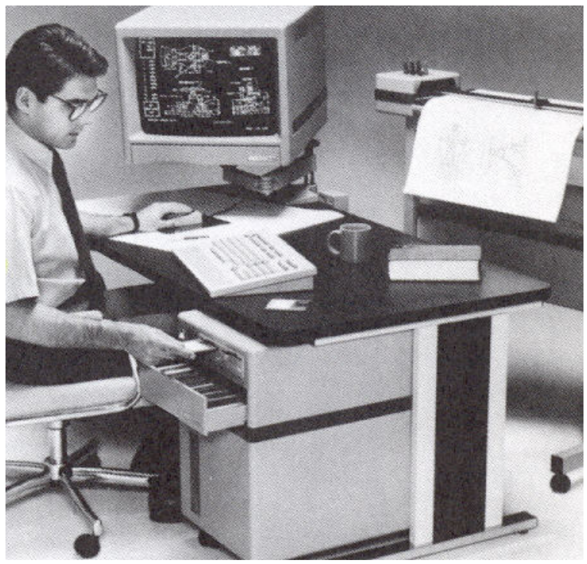

Figure 21.3
BruningCAD Easydraf$^2$ System

During the next several years, BruningCAD developed its own workstation built around a Motorola 68000 microprocessor, a 19-inch 16-color 1024x768 display and a 14.5MB disk. Two version of the software were offered, Easydraf$^2$ Architectural and Easydraf$^2$ Mechanical. Prices started at $41,900 which was considerably higher than comparable PC-based system.

In October 1984, AM International, which was in the process of emerging from bankruptcy, folded BruningCAD into the rest of the Bruning operation in order to reduce overhead expenses. A year later, the company's CAD-related staff had been reduced from 46 to just 15 people and the remnants of this activity were sold to Holguin Corporation of El Paso, Texas. At the time, there were perhaps 1,500 Easydraf$^2$ systems installed worldwide, 900 of which were in the U.S. Mutoh Industry Ltd. acquired the Japanese rights to the software. Although Holguin maintained the staff in Tulsa for a period of time, the business eventually faded away.

**Cadkey (Micro Control Systems, Baystate, Kubotek)**

This company was founded in 1981 in Windsor, Connecticut by Livingston Davies and Peter Smith as Micro Control Systems. Its first product was a three-

[12] *The Low Cost CAD/CAM Systems Market*, International Data Corporation, May 1982, Pg. 36

 

dimensional digitizer called the Perceptor. This was followed by a similar device called the Space Tablet. In 1982 the company introduced a simple software package that enabled users to view the scanned data as three-dimensional isometric or perspective images. The package, which ran on both Apple II and IBM-compatible PCs, was called Space Graphics and sold for just $475.

The company launched CADKEY in 1985 as a PC/DOS program partially to utilize the data generated by its three dimensional scanners. It targeted mechanical designers, especially those who were creating products that involved NC manufacturing operations but were also interested in producing quality mechanical drawings. CADKEY's share of the PC CAD market peaked in the late 1980s at about 14 percent, behind AutoCAD and VersaCAD. CADKEY was a functionally rich three dimensional wireframe design and drafting package. Many customers, including Boeing, purchased it to complement the high-end design systems they also used.

By 1992, the company was doing about $12 million per year and Livingston Davies recruited Malcolm Davies, who had recently left Autodesk, as president.[13] Livingston Davies and Peter Smith left their day-to-day management roles at the company although they remained members of its board of directors. In an attempt to jump-start its business momentum, the company reduced the list price of the CADKEY software from $3,500 to $495 and DataCAD (an architectural drafting package it had acquired several years earlier) from $2,000 to $150. This greatly increased the number of users. As an example, the DataCAD user base went from a few thousand to over 50,000 in less than 12 months.

By late 1994 it was obvious that the market was not as price-elastic as expected and overall revenue was not growing. Malcolm Davies left and Livingston Davies returned as president and the price of CADKEY edged up to $795. In early 1995, Cadkey released CADKEY for Windows and before the year was over shipped 25,000 copies.

The company also marketed several third party packages as part of its product line including FastSURF from a company by the same name that incorporated NURBS surfaces and DRAFT-PAK, a mechanical drafting symbol library developed by Baystate Technologies, one of the company's dealers. In late 1995 the company was also developing ADVANCED MODELER, a solid modeling program that used the Shapes geometric kernel from XOX Corporation. At the start of 1996 the company underwent a substantial retrenchment and shifted to a software publishing business model and CADKEY development was moved to India. Baystate was signed up as the master distributor for CADKEY.

In mid-1996, Baystate, headed by Robert Bean and located in Malborough, Massachusetts, acquired all rights to the CADKEY package and related Cadkey software products. At that point, there were about 200,000 copies of CADKEY in use. One of the first steps Bean took was to replace the XOX geometric kernel with ACIS from Spatial Technologies.[14] In March 1997, Baystate began selling CADKEY 97 that incorporated ACIS 2.1 solids modeling. The price was now $1,995, up substantially from a few years earlier but still half the cost of competitive systems such as SolidWorks or Autodesk Mechanical Desktop.

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[13] The two Davies are not related.
[14] *Engineering Automation Report*, August 1996, Pg. 13

A year later, Baystate acquired FastSolid and FastSURF from a joint venture consisting of FastSURF Incorporated and Advancing Geometrics. A combination of CADKEY, Draft-Pak, FastSolid and FastSURF was sold as the CADKEY DESIGN SUITE for $3,995 while the base package remained $1,995. Baystate changed its name to CADKEY Corporation later in 1998.

With CADKEY 99, the company had a reasonable modeling solution although it still did not incorporate parametric definitions nor was assembly modeling easy. The program's modeling capabilities were quite fast since CADKEY 99 did not incorporate a history tree describing how the model was constructed. The downside was it increased the effort required to modify models. CADKEY also began using the Web as a sales vehicle in late 1999. In December 2001, the company announced a totally redesigned package called CADKEY GraphX Version 20 that incorporated object-oriented software techniques, the HOOPS graphics routines and ACIS 6.3.6.

While its products were improving, the company itself hit a major snag in 2003. Back in 1991, Baystate had been sued by another vendor of add-on CADKEY software, Harold L. Bowers, who operated as HLB Technologies. HLB accused Baystate of copying one of its software products. The case dragged on for 12 years but was finally decided in HLB's favor in 2003. Baystate was required to pay HLB $5.27 million ($3.87 million plus interest), money that Baystate did not have. In August 2003, Baystate filed for Chapter 11 bankruptcy.

Initially, it was thought that International Microcomputer Software, Inc. (IMSI), the vendor of TurboCAD, would acquire the company. In November 2003, Kubotek, a Japanese company that had acquired a 17 percent interest in Baystate in 1996, purchased the company for $3.6 million. HLB got about $750,000 as a result of this deal. The company was renamed Kubotek USA with Naotake Kakishita as president and Bean as chief operating officer. The CADKEY product itself was renamed KeyCreator.

**CalComp Systems (ISICAD)**

CalComp Computer Products was founded by three engineers from Rockwell's Autonetics Division in 1959. Initially focused on military research, the company launched the industry's first incremental digital plotter in 1961. By the early 1970s it was the leading manufacturer of digital plotters and had expanded into other areas including plug-compatible peripherals for IBM mainframe computer. This latter activity involved the acquisition of Century Data Systems and was a financial disaster that is outside the scope of this book.

The data storage business was sold to Xerox in 1979 and the company, itself, was acquired by Sanders Associates in 1980. In addition to its own product line of graphics terminals, Sanders manufactured the 3250 display for IBM during the early and mid 1980s. This business eventually dried up when IBM introduced the 5080 raster graphics system. Most of the company's plotter sales were in support of other companies' CAD systems. Sanders grouped together the CalComp Systems business described below, the CalComp plotter business, the Talos digitizer business which it had also acquired and its own graphics terminal business in a single organization and marketed all these products under the CalComp brand name.

CalComp began the development of its own CAD system in 1975. The company's first CAD product, the IGS-500, was introduced in 1979, about the same time that

 

CalComp Systems was established. The IGS product line also included the IGS-300 and the IGS-400. These systems were based on a 16-bit minicomputer manufactured under license from a French electronics firm, Société Européenne de Mini-Informatique et de Systèmes (SEMS), a division of Thomson-CSF. Each terminal incorporated a high speed graphics processor called the Picture Processor which handled operations such as pan and zoom locally. Each terminal contained a 250KB high-speed memory that held the entire active drawing. The basic unit had a 15-inch monitor with 416 by 300 resolution. A 20-inch unit was 1024 by 768 resolution was also available.

The basic IGS-300 was intended to be a satellite system to an IGS-500. It had a 192KB memory, a 40MB disk, a 15-inch low resolution graphics display, and a separate alphanumeric display. The IGS-400 incorporated a hard disk drive, dual floppy drives and supported one or two terminals. The IGS-500 was a more powerful system capable of supporting six or more local terminals or remote IGS-300 systems. A high resolution 20-inch display was also available. Basic systems ranged from $90,000 to $160,000 while additional terminals cost $55,000 each with the smaller display. A color raster display was introduced in mid-1982 for $78,000.

The IGS software handled two-dimensional drafting fairly well. One problem was that the computer being used was not generally available to other commercial accounts and CalComp had to create its own operating system as well as a FORTRAN compiler. Another problem was that the company offered few task-specific applications other than architectural drafting and piping and instrumentation diagrams (P&IDs).

In mid-1984, CalComp Systems introduced a new product line, the System 25. It was based on a Masscomp computer and the CalComp built Picture Processor. The initial Masscomp systems used dual 10-MHz Motorola 68000 microprocessors, UNIX and Ethernet. The typical configuration included an alphanumeric display, a 20MB disk and either a 20-inch monochromatic or 19-inch color display. The software supported basic drafting functions with an emphasis on facilities planning and architectural design.

Figure 22.4
CalComp System 25

The System 25 software was functionally identical to the earlier IGS software. Each Masscomp computer was capable of supporting two workstations. A single system with a monochromatic terminal and a CalComp 945 plotter had a list price of $95,000. A second workstation cost $$37,000.

The management staff in mid-1985 consisted in part of:

- William Conlin – president of CalComp Computer Products
- Louis DeBartolo – vice president and general manager of CalComp Systems
- William O'Brien – group vice president, marketing and sales
- Jim Gowan – vice president and general manager, international
- Doyle Cavin – vice president, technology
- Joe Fornataro – vice president, system sales
- Warren Winterbottom – vice president, OEM product sales (previously vice president of marketing for the Systems division)

Conlin eventually joined SDRC's board of directors after retiring from CalComp. O'Brien[15], Gowan and Cavin were all former Tektronix executives while Winterbottom went on to work for both Intergraph and Bentley Systems.

CalComp Systems never had much more than about $30 million in annual revenues. In mid-1985, the CalComp Systems Division of Sanders Associates acquired the CADplan software product line from Personal CAD Systems (P-CAD) for $7.5 million and renamed it CADVANCE. This software initially sold for $2,500 per copy. The acquisition did not go well and Sanders sued P-CAD for $22 million claiming that the company had misled it about the financial health of its AEC business prior to the acquisition.[16] A major problem that CalComp faced trying to sell CAD systems and software was that it competed with turnkey CAD systems vendors who were some of CalComp's largest customers for plotters and other peripheral devices.

Sanders Associates was acquired in 1986 by Lockheed which also owned CADAM, Inc. When Lockheed ran into it own financial problems, it sold off several divisions including CADAM. It was expected that CalComp was also going to be sold but either no buyer emerged or Lockheed changed its mind and kept the company. For the next few years CalComp did fairly well as an independent division of Lockheed focused on plotters and other peripheral devices.[17]

CalComp pulled out of the CAD systems business in May 1987 when it sold CalComp Systems to ISICAD based it Ellwangen, Germany and subsequently focused its resources on three primary product lines: plotters, printers and digitizers. ISICAD opened an office in Anaheim, California and marketed CADVANCE for a number of years. The president of the U. S. operation was John Arnold.

CalComp continued to produce a wide range of plotters using just about every technology currently available including increasingly popular inkjet units that were

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[15] Bill O'Brien was my boss at Tektronix in the late 1970s.

[16] The lawsuit was settled in 1987 but the terms were not disclosed.

[17] In 1991, CalComp acquired one of its major distributors, Access Graphics of Boulder, Colorado. The president of Access Graphics at the time was John Ramsey, whose daughter, JonBenet Ramsey, was murdered on December 26, 1997. Access Graphics was split off from CalComp in 1993 and made a separate Lockheed division.

 

quickly replacing pen plotters and expensive electrostatic devices. Lockheed merged with Martin Marietta in 1995 to form Lockheed Martin.

CalComp Computer Products and Summagraphics merged in July 1996 and became CalComp Technology, Inc. This new entity assumed Summagraphics' position on NASDAQ with Lockheed Martin owning about 90 percent of the new company. The next few years saw CalComp Technology's sales slowly decline as the company struggled with new inkjet technology and increased plotter competition from Hewlett-Packard. Trading in CalComp Technology stock was terminated in January 1999 and the company was liquidated in May 1999.

CADVANCE software was acquired in 1995 from ISICAD by Furukawa Information Technology, Inc., a software distributor located in Anaheim, California. Founded by Takashi Furukawa, the company continues to sell CADVANCE, currently priced at $1,995 per copy. See section below on ISICAD.

**Cimlinc(Cadlinc)[18]**

Cadlinc was founded in April1981 by John West who had previously been involved with the sale of NC supplies and Mike Sterling, the founder of Systems Associates, a manufacturing consulting company established in 1973. The latter company was the U. S. distributor of an NC software package, Graphical Numerical Control (GNC) and a surface geometry package, Polysurf, both developed by the CAD Centre in Cambridge, England. The GNC software was also sold by Prime Computer. In the process of starting Cadlinc, Systems Associates was folded into the new company. West was primarily the public face of the company while Sterling became vice president of product development for the new company.

The third key member of the start-up team was Dr. Martin Newell who had earlier been associated with the CAD Centre in Cambridge and then at the Xerox Palo Alto Research Center (PARC) where he worked on interactive graphic systems with John Warnock who subsequently co-founded Adobe Systems. While Cadlinc was initially headquartered in Elk Grove, Illinois, Newell stayed in Palo Alto and ran the company's research center there while Sterling ran other software development from Troy, Michigan. Eventually, the company's operations were consolidated in Itasca, Illinois.

In four rounds of funding, the company raised $24 million in venture capital from a number of investment firms including Kleiner, Perkins, Caufield and Byers and The Hillman Group.[19] The company's early products fell into three categories. Initially, it manufactured its own UNIX workstations built around the Motorola 68000 microprocessor, Ethernet and a proprietary graphics processor. It also developed design and drafting software and adapted the GNC NC software to work on the Cadlinc workstation. It probably can lay claim to being the first vendor to sell turnkey CAD/CAM systems on networked UNIX workstations since the Apollo workstations being used by Auto-trol Technology and Calma were not true UNIX systems.

According to Sterling, he knew Jim Clark, the founder of Silicon Graphics, and attempted unsuccessfully to get Cadlinc's financial backers to fund Clark's early graphics

[18] The company changed the spelling from Cimlinc to CIMLINC around 1989.
[19] The Hillman Group was run by Henry Hillman, the half-brother of Howard Hillman, the primary investor in Auto-trol Technology. See Chapter 9.

 

work. This was about six months after Auto-trol had likewise turned down an opportunity to work with Clark as discussed in Chapter 9.

Throughout the 1980s Cadlinc invested considerable resources in its proprietary workstations at a time when other turnkey vendors such as Calma, Computervision and Auto-trol Technology were switching to industry standard workstations manufactured by Apollo Computer, Sun Microsystems and others. While, its workstations and user interface were fine tuned for its own software, building computer hardware, including a proprietary floating point processor, turned out to have a negative impact on the company. Cadlinc always seemed to be playing catch-up to other workstation vendors. For example, for some time after Apollo had switched to Motorola’s 68020 microprocessor, Cadlinc was still using the 68000.

The company’s systems were reasonably priced. In mid-1985, a CIM Station (a basic workstation with 2.5MB of memory, a 30MB disk and a 19-inch 256 color monitor) sold for $39,500. Basic design software was an additional $10,500 while surface design and NC software packages were $9,500 each. One can assume that packaged solutions sold for less than the sum of these prices. The company also sold the CIM Manager, a server with up to 800MB of disk storage. Very little third-party software was available.

The company’s strongest marketing points were that West and Sterling had been involved in the NC business for over ten years and the software’s user interface was one of the best then on the market. West was a very dynamic individual and the company received substantial positive press coverage. In November 1985, the company changed its name to Cimlinc. The following year revenues reached $25 million with over 200 employees and everyone expected the company to go public. While the company’s revenues subsequently increased to over $35 million (about half hardware and half software), the IPO never happened.

In 1986 the company changed the system nomenclature to Power CIM. The new workstation used a 68020 processor, a Motorola 68881 floating point processor and a separate 68000 to control input/output. The system had 4MB of memory, an 86MB disk (expandable to 2GB) and a 19-inch 1024 by 792 color display. This was one of the first systems where the user interface consisted primarily of on-screen menus and a mouse. The software was renamed CIM CAD and included solid modeling functions. The manufacturing software was called CIM CAM. Monochromatic workstations started at $11,990 and color workstations at $16,990. CIM CAD software was $4,495 while CIM CAM was $6,495.

 

Figure 21.5
Cimlinc Modular Workstation

By late 1987 the company realized that it could no longer compete in the workstation market and Cimlinc became a pure software vendor. PCs were coming on strong and the sales force was finding itself spending a considerable portion of its time defending the company's hardware strategy. Cinlinc ported its software to Sun Microsystems SPARCstations and in mid-1989 the company reduced its software prices by as much as 77 percent. A Sun workstation with basic CAD software sold for just $19,500.

In 1990 the company was split into two operating units, the AMT (Advanced Manufacturing Technology) division which continued to maintain its CAD/CAM applications and a new group that began to pursue information management applications. The design and NC packages were renamed ExpertCAD, ExpertCAM and ExpertCAD 3D with prices ranging from $2,995 to $8,995. The software was supported on both Sun UNIX workstations and on Windows PCs. AMT also offered a more advanced UNIX software solution for tool and die production called ToolDesigner that was initially priced at $10,000.

Gradually, Cimlinc began to refocus its energies in the data management area. Its target was managing the flow of design and manufacturing information with a product called LINKAGE which was introduced in 1991. This software was built around a macro language, *Script*LINK, used in its CAD/CAM software. LINKAGE ran on UNIX workstations at a time when it probably should have been ported to the PC. Mike Sterling left the company around 1995 due to the change in the company's direction.

The AMT division of Cimlinc was acquired for $6 million by Softech in late 1997 which it still operates it as this is being written. Among other products, Softech is also the current vendor of CADRA. By 2001, the data management portion of Cimlinc simply disappeared as a company.

**CoCreate (Hewlett-Packard Mechanical Design Division)**

Hewlett-Packard was an early vendor of minicomputers and desktop graphics systems used for engineering design and analysis, either as a supplier to various turnkey systems vendors or by selling this equipment directly to end users. The two centers of activity for desktop computer systems were Fort Collins, Colorado and Boeblingen, Germany.

From an application point of view, Fort Collins concentrated on electronic design and drafting, especially electronic schematics. HP spent a significant amount of energy trying to develop electronic CAE software internally. This effort, led by C. Richard Moore, who subsequently left to become CEO of Valid Logic, was terminated in October, 1984. HP then acquired Salt Lake City, Utah-based Cericor in late 1985 for $32.5 million. By 1990, this operation proved incapable of competing with companies such as Mentor Graphics and the EDA business was closed down.

Separately, HP's facility in Boeblingen began developing mechanical software. The first product, introduced in 1980, was an object-oriented two-dimension package called HP Design. It used parametric techniques that proved to be hard to use. Although they added a FEA package from a software firm in England and a NC package from another vendor Germany, HP Design was not widely used outside of HP itself. This package focused on design tasks at a time when customers were looking for desktop drafting solutions. Some of the problems HP had with the parametric features of this software led it down a development path that avoided history-based software solutions as described below.

In late 1981, HP introduced a new product, HP Draft. This was a drafting package the company licensed from Skok Systems, a South African software firm. HP licensed the package for resale to mechanical users while Skok continued to sell it to AEC users. The HP development staff in Boeblingen, under the direction of Tillman Schad, worked from about 1981 to 1984 developing a new package specifically intended for mechanical drafting called ME Series 10.

At about the same time, HP restructured this operation as its Mechanical Design Division (MDD). In addition to ME 10, MDD also developed a three-dimensional design package using the Romulus solids modeler. Introduced in 1985 as ME Series 30, it was primarily an analytical modeler with no free-form surface capability. The price in the U. S. was $14,500.

To satisfy the need for three-dimensional surface modeling, HP introduced ME Series 50 in late 1985. This package was based on Graftek (a division of Burroughs at the time) software. (See section on Graftek below.) The timing was bad in that HP earnings had been declining and in a cost-savings move, ME 50 was withdrawn from the market within nine months of its introduction.

A typical ME 10 systems sold for about $40,000 including an HP workstation. At the time, both MDD and the electronic CAE systems were managed by HP's Design Systems Group which was also responsible the company's engineering workstation business. The company also sold a reduced function version of ME 10 called ME Series 5 which sold for about $20,000 including hardware. The latter product was not particularly successful in that there was growing interest in PC-based solutions such as Autodesk's AutoCAD which sold for less than half the cost including hardware and software.

The Design Systems Group was managed by Bill Parzybok while the electronic engineering activity was run by Larry Porter and the mechanical engineering operation in Boeblingen was run by Tilman Schad. At about the same time, HP became a major player in the engineering plotter business and also acquired Apollo Computer, significantly increasing its share of the engineering workstation market.

The company's entry into the CAD software market put it on a collision course with many of Apollo's OEM customers who were not particularly pleased to be competing with one of their primary suppliers. HP tried to dampen objections without much success by establishing a separate sales force for its CAD systems.

In early 1992, HP renamed the existing products Precision Engineering/ME 10 and Precision Engineering/ME 30. At the same time, it introduced a new solids-based system called Precision Engineering /SolidDesigner. This latter package was initially based upon Spatial Technology's ACIS geometric kernel. At the time, HP owned about a 10 percent interest in Spatial. Being an early adopter, HP had to develop a fair amount of add-on technology to ACIS, especially in the surface modeling area. HP proceeded down its own development path and never implemented newer releases of ACIS. Within several releases, little of the original ACIS code remained in SolidDesigner.

SolidDesigner differed from most contemporary CAD systems that used history trees to maintain the relationships between graphic features. It used an approach called dynamic modeling that allows users to manipulate geometry irrespective of what was done to the model earlier. There are pros and cons of both approaches – suffice it to say that the HP approach was different than most other systems on the market. SolidDesigner retained many of the functional characteristics of ME 30 except that it no longer supported tablet menus. A multi-dial function box was used to pan, zoom and rotate shaded models on HP workstations. Detailed mechanical drafting continued to be done with ME 10. Solid Designer software prices started at $7,500 which was competitive with PTC's Pro/ENGINEER.

Separately, the company marketed a PDM package called WorkManager which was an upgraded version of an earlier package called the Data Management System. WorkManager was implemented to work with data from design and drafting systems other than just the ones sold by HP. The intent was to provide a data management solution that did not require a dedicated system administrator.[20]

The friction between HP and its OEM customers in the mechanical CAD market eventually led HP to restructure MMD as a separate wholly-owned subsidiary in 1996 called CoCreate with Schad as president. In September 2000 CoCreate was acquired from HP by two European investment firms, 3i PLC and Triton Fund, and the company's employees. The two investment firms probably owned over 90 percent of the company. Schad continued as CEO of the newly independent company which was still located in Fort Collins, Colorado. The company's chief operating officer was Gert Deiss and vice president of product development was Ulrich Mahle, both of whom were long term HP and CoCreate employees.

In the late 1990s CoCreate began promoting a new collaborative engineering package called OneSpace that enabled engineers and others located at geographically separate locations to work together on the same design. One participant controlled the design review session while other participants viewed any changes made to the product model. This control could be shifted between participants although changes could only be made by someone who actually had the design software on their computer. Eventually Solid Designer was renamed Designer Modeling, ME 10 became Designer Drafting and

[20] *Engineering Automation Report*, August 1992, Pg. 10

WorkManager morphed into Model Manager. By 2006 the software was being fully developed using Microsoft's .NET platform and it no longer retained any vestiges of its UNIX roots.

Schad was replaced as CEO in March 2002 by William Gascoigne who had been vice president of worldwide marketing at Applicon and more recently executive vice president of worldwide operations at SDRC. Hansjoerg Pleggemars, who joined the company in 2000 as CFO was appointed COO in July 2006. At the same time, ownership of the company changed once again when HBK Investments L.P., a large U.S.-based hedge fund, acquired CoCreate.

From 2000 through 2006, CoCreate's revenues were in the $75 million per year range although profits improved significantly during the period. One reason revenues stagnated was that the company began offering its software on a monthly subscription basis in addition to selling fully paid-up licenses. While this generated many new customers, it did defer some revenue to future years. The company's headquarters were basically split between Fort Collins and Sindelfingen, Germany with its approximately 300 employees about evenly divided between Europe, The U. S. and Asia.

Ownership of CoCreate changed once again in December 2007 when PTC completed the acquisition of the company for about $250 million. At the time it committed to continue support of CoCreate's software as stand-alone products as well as integrate the technology with its own products. At the time of this latest acquisition, CoCreate had about 5,000 customers.

**Cognition**

Other than the fact that it has exhibited impressive staying power and has been run by some of the CAD industry's early pioneers, I probably would not have included Cognition in this chapter. Cognition Incorporated was founded in February 1985 by a group of 11 experienced industry managers led by Philippe Villers, a founder of Computervision as well as Automatix, a manufacturer of robotic and artificial vision systems. Villers had started Automatix in 1980 along with Mike Cronin who had been vice president of sales and later vice president of R&D at Computervision. In 1984, investors in Automatix felt a change in management was needed and Cronin replaced Villars as CEO of the company.

Villars, being a serial entrepreneur, started Cognition to focused on the development and marketing of mechanical computer-aided engineering (MCAE) solutions. Among the other founders were George Stienke, vice president of marketing who was formerly executive vice president of marketing at Intergraph, Kenneth Schroeder, vice president of research and development who was formerly manager of General Electric's Industrial Electronics Development Laboratory, Robert Light, product line manager for MCAE who was formerly technical manager of MIT's CAD Laboratory and Douglas Wilson, manager of systems architecture who was formerly a manager of MIT's project Athena, a 1,000 terminal computing network. Other founders and early employees had equally strong backgrounds.

Based on Villers reputation within the financial community, the company was able to raise $15.5 million in two rounds of funding during its first two years including $2 million from the founders. One has to assume that much of the latter amount came from

Villers. Investors included Harvard Management Corporation, MIT, and Eastech Limited Partnership. As mentioned above, Eastech was also an early backer of Aries Technology.

The company's initial product, Mechanical Advantage 1000 (MA1000) was introduced at AUTOFACT '85 in Detroit that November. The company planned to offer both unbundled software and complete turnkey systems that consisted of a Digital MicroVAX II host and up to five IBM PC AT workstations. The software enabled users to sketch, analyze and optimize conceptual designs. The intent was to have this data passed on to traditional CAD systems via IGES in order to complete the designs and produce engineering drawings.

The MA1000 software was called The Optimizer. It included SketchPad, MathSolve, first-order analysis tools, online engineering handbooks and a data management tool called the Intelligent Notebook. MathSolve equations could be linked to specific dimensions defined with SketchPad. The engineering handbook content resulted from an agreement the company negotiated with McGraw-Hill. A three-seat MA1000 was priced at $130,000. Unbundled Optimizer software was $37,500.

After some development delays, the company began shipping MA1000 systems in late 1986. Revenues in 1986 were only $730,000 and with 95 employees it was burning up cash at a rapid rate. A higher performance system, the MA1500/GPX, using the Digital VAXstation II/GPX was introduced in late 1986. While these systems demonstrated very well, they just did not seem to create the necessary level of interest among potential buyers who were mostly still trying to automate basic drafting tasks.

The early expectations were that Cognition would take off like a rocket. It never happened. One problem was that the technology appealed to individual engineers but senior managers, those who controlled budgets, were still focused on automating basic design and drafting tasks. George Stienke resigned in early 1987 and the company started looking for ways to expand its product offerings. One area it focused on was cost estimating. The resulting product, Cost and Manufacturability Guide, was eventually a key part of the company's survival as a viable business entity. Over time, the company phased out of the hardware business and became a pure software play.

One aspect of this transition was the acquisition of SuperCads, Inc., a software firm started by Shyamal Roy in 1981. The SuperCads software was a three-dimensional wireframe package. Cognition marketed SuperCads without a great deal of success.

By early 1988 the company was in substantial financial difficulty and Automatix, under Mike Cronin, acquired the assets of Cognition Inc. and hired most of the company's remaining employees. Automatix ran the former Cognition activity as a subsidiary legally named Supercads, Inc. but utilizing the Cognition trade name. This subsidiary, of which outside investors owned about 29 percent, continued to struggle with revenue running between $1 and $2 million annually. Cronin stepped down as CEO of Automatix in 1990 to become full time CEO of SuperCads. He was replaced at Automatix by Ofer Gneezy.

By July 1992 Automatix had incurred losses on this activity of $4.3 million and it sold the Cognition business (still legally SuperCads, Inc.) to Cadema Corporation for $1.8 million in cash and notes and Cronin took over running Cadema.[21] Before this transaction, Cadema was nothing more than a shell corporation which had earlier been engaged in medical research activities. It had some cash left over from these previous

[21] *Electronic News*, June 8, 1992

endeavors and was looking for opportunities to invest it. This new ownership did not last long and in May 1993 Cadema sold the Cognition assets to Cronin and a group of other investors.

Over the next few years, Mechanical Advantage was refined to provide three main capabilities: tolerance analysis, functional modeling and parameter analysis. In the 1999 time frame, about 30 percent of the Mechanical Advantage customers were using the software just for tolerance analysis. Prices started at $12,000 per license.

Cost and Manufacturability Guide eventually morphed into a product called Cost Advantage that assisted companies in predicting manufacturing costs before a design was completed. A key component of this software was called Model Builder. It provided the information needed to link manufacturing costs to design features. Cost Advantage software started at $20,000 for Model Builder plus one floating user license. Additional software was $5,000 per copy.[22] This turned out to be Cognition's key product activity for the next few years.

Today, the surviving company, Cognition Corporation, still markets Mechanical Advantage and Cost Advantage but with increased emphasis on two new initiatives, Cognition Cockpit and Enterprise Cost Management (ECM). According to the company, Cockpit is a tool set and knowledge management system which can be used to support Design For Six Sigma. ECM is a product cost management system. In 2006, Dale Gallaher was named president of Cognition. Mike Cronin is still chairman and CEO while his son David is manager of business development.

**Control Data Corporation (Control Data Systems, ICEM Technologies)**

Control Data Corporation (CDC) was one of the early manufacturers of large-scale scientific computers including one of the first "super computers," the CDC 6600, introduced in 1964. CDC first became involved with CAD solutions in 1963 when it acquired the rights to Itek Corporation's Electronic Drafting Machine and established its Digigraphics Division in Bedford, Massachusetts as described in Chapter 6. In the late 1960s, CDC realized that the Digigraphics operation was "wine before its time" and shut the money-loosing operation down.

In the early 1970s, CDC was a profitable computer vendor selling a broad range of machines to scientific research centers and manufacturing companies. It was also a leading participant in the business of selling time-sharing services. Given the communication capabilities then available, it was not feasible to provide highly interactive applications such as CAD on a time-sharing basis.

Alan Christman joined CDC in 1970 as general manager of manufacturing industry marketing. Over the next few years the company began to look at ways it could provide more complete design and manufacturing solutions to its customers. One option that was fairly quickly rejected was to resurrect the Digigraphics activity. CDC also decided that it did not want to develop CAD software from scratch. The result was that the company signed a license agreement with Manufacturing & Consulting Services (MCS) in the mid-1970s for that company's AD-2000 software as described in Chapter 15.

AD-2000 formed the basis of what CDC called its ICEM (Integrated Computer-aided Engineering and Manufacturing) program. The software was implemented on the

[22] *Engineering Automation Report*, June 1999, Pg. 6

 

company's 32-bit mid-range computers as well as on its 60-bit supercomputers such as the CDC 6600. The primary user terminal at the time was the Tektronix 4014. CDC established its own software group to extend the capabilities of AD-2000 as well as support the company's computer systems. Working with MCS-provided updates to AD-2000 proved to be difficult for CDC and, in early 1982, the company acquired a fully paid-up license for AD-2000 much as Auto-trol Technology did around the same time. At this point the name for the product was changed to CD/2000 and then later ICEM DDN.

While the company put substantial effort into making CD/2000 a viable product, the impression most people had was that CDC was simply using the software to help sell mainframe and minicomputer computer systems. The company invested a fair amount of effort in making the software run efficiently on its computer systems but relatively less on actually improving CD/2000's functional capabilities. CDC also continued to provide technical time-sharing services through a division called CYBERNET, particularly in the area of structural analysis and electronic circuit design.

One area of interest was solids modeling which the company saw as an emerging technology. Christman remembers reading an article in *Business Week* that described how Boeing was experimenting with Synthavision solids modeling software from MAGI. CDC subsequently licensed Synthavision and created a link to CD/2000 for exchanging data between the two packages. The company ended up selling relatively few copies of Synthavision, primarily because of performance issues. Christman, who is now a principal at CIMdata, described the software as "watching paint dry."[23]

Eventually the software expanded to encompass a broader range of engineering tasks including data management and NC applications. The company also added software, ICEM Electronics, that enabled engineers to merge electronic design with mechanical design. A single user system utilizing the company's Cyber 120-40 computer with a subset of the ICEM software was introduced in mid 1983 for $50,000. The Cyber 120-40 was actually a repackaged Data General S20 computer. A six-user system started at $161,000.[24]

Major customers included Bendix in Kansas City, Los Alamos National Laboratory, Volkswagen and Fischer-Price, the manufacturer of children's toys. In June 1986, CDC acquired an NC software firm, ICAM Technologies, of Pointe Claire, Quebec to expand its NC capabilities. Also, about the same time, CDC began selling a product line of UNIX workstations, the CYBER 910-300 Series, which were basically repackaged Silicon Graphics workstations.

In the late 1980s CDC began to put increased focus on PDM software. The company's product was called EDL (Engineering Data Library). Initially it was implemented on CDC computers but by mid-1991 CDC was also supporting Sun and SGI UNIX workstations with Hewlett Packard, IBM and Digital versions in development. EDL software was sold on a per workstation basis with the basic network information manager priced at $3,500 per seat. A complete system including a release manager and product structure software was $6,500 per seat.[25] The portion of CDC that included the company's CAD/CAM and PDM activity was subsequently renamed Control Data Systems, Inc. or CDSI.

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[23] Interview with Alan Christman on July 18, 2006
[24] *Computer Aided Design Report*, August 1983, Pg. 9
[25] *Computer Aided Design Report*, July 1991, Pg. 7

As described in Chapter 17, CDSI and SDRC established a joint venture in 1992, Metaphase Technology, Inc., to pursue the PDM market. CDC contributed the EDL software and a number of individuals to this venture. SDRC soon became the driving force behind Metaphase in regards to both development and marketing. Then in late 1996, SDRC bought out Control Data's interest in Metaphase.

In 1993, CDSI became ICEM Technologies with ICEM DDN (previously called CD/2000) as the company's primary product. One change was increased interest in surface geometry software developed by the company's European operation in Frankfurt, Germany. ICEM SURF started out as an internal development project at Volkswagen. It soon gained a reputation within the automotive industry as one of the leading tools for body styling and eventually it became ICEM Technologies' primary product with ICEM DDN deemphasized. ICEM SURF quickly gained a reputation as a leading package for automotive styling, particularly for creating and editing what that industry referred to as Class A surfaces. The company also renewed its focus on manufacturing software with the introduction of PART, an NC package that used feature recognition and generative expert system technology. Another package, ICEM Solidify was introduced that facilitated the conversion of wireframe data to ACIS-based solids models.

In 1998, ICEM Technologies was acquired by PTC as described in Chapter 16, primarily for its ICEM SURF software. PTC spent several years attempting to integrate ICEM software with Pro/ENGINEER and eventually decided that it had more on its plate than it could deal with. ICEM was sold to a group of English investors in August 2002 and was subsequently operated as ICEM Ltd. in Southampton, England. In 2005, the company expanded its product line with the introduction of ICEM Shape Design (ISD), a parametric modeling package developed on Dassault Systèmes CAA V5 architecture. Then in mid-2007, Dassault acquired ICEM for the equivalent of $69 million.

**Gerber Systems Technology (Gerber Scientific)**

The Gerber Scientific Instrument Company was founded in 1948 by H. Joseph Gerber, the 1994 recipient of the National Medal of Technology. Initially the company produced mechanical data reduction instruments used before electronics and computers revolutionized that field. Over the years, Joe Gerber was awarded 675 patents, including a number after he passed away in 1996 at the age of 72. Gerber is perhaps best known today for the precision cutting machines he developed for the apparel and shoe industries.

Gerber went public in 1961 at $6 per share and shortly thereafter developed the photoplotter which revolutionized the production of printed circuit board artwork. For many years the company was the leading vendor of photoplotters. The company also began manufacturing numerically-controlled sewing machines and CAD/CAM systems.

The company's name was changed to Gerber Scientific, Incorporated in 1978. By 1980 the company had overall revenues of about $75 million and its stock was listed on the New York Stock Exchange. Gerber Scientific was organized as a holding company with four primary operating units.

- Gerber Scientific Instruments – precision plotting systems including photoplotters and precision pen plotters.
- Gerber Systems Technology – CAD/CAM systems.
- Gerber Scientific Products – custom computer-controlled manufacturing system.

- Gerber Garment Technology – layout and cutting systems for the garment industry.

In addition to a wide range of plotters and photoplotters, Gerber Scientific Instruments (GSI) marketed a PCB layout and artwork system called the PC-800. Various version of this system sold for $35,000 to $50,000 plus the cost of a plotter and/or photoplotter. The latter typically sold for $60,000 to over $500,000. The PC-800 used a Hewlett-Packard 2100 Series 16-bit minicomputer with 32KB of memory and dual 8-inch floppy disks. The user terminal consisted of a relatively small monochromatic raster display and a Gerber 8200 digitizer. Typical operation involved the user manually laying out a circuit board, digitizing the layout, editing the data, plotting the layout for checking purposes and then outputting the data to either an on-line or off-line photoplotter.[26]

The PC-800 was a fairly simple system but it worked well. By 1981, the company was selling $12 million annually of PC-800 products and had an installed base of 250 systems.[27] By 1987 it had installed 775 such systems. GSI also sold flatbed plotters as large as 6 feet by 24 feet and drum plotters up to 48 inches wide. These were all extremely accurate and reliable machines.

Gerber System Technology (GST), originally Gerber's Systems Division, became a quasi-independent company in 1981 with Wilbur (Bill) Mann as president. It was 80 percent owned by Gerber Scientific and 20 percent by the public. GST went public in 1981 at $12.50 per share. At the time it had about 300 employees and was doing over $17 million in annual revenue. Gerber was an early licensee of Pat Hanratty's ADAM software which served as the starting point for the company's mechanical design and NC software, first introduced in 1974 as the IDS-3. About 100 of these systems were sold before it was replaced by the IDS-80, launched in April 1980.

The IDS-80 was a traditional multi-user turnkey CAD system that used a Hewlett-Packard 1000F minicomputer (also called the 2117F) as its host with up to 512KB of main memory. Each workstation also included a smaller HP 1000E computer to handle local graphic functions. Since early systems used Tektronix storage tube displays, this configuration enable the software to redraw images on the displays without putting a heavy processing load on the host computer. A color raster version of the workstation using Lexidata components was introduced in 1982. An IDS-80 system with a single workstation was priced at $190,000 while a six workstation system cost about $450,000.

Although still based on the early ADAM software, the IDS-80 incorporated a more sophisticated database capability and Gerber-developed NC software. The system was particularly adept at machining compound curved surfaces. Autopost was software used to create NC post processors. The company also marketed a finite element modeling package based upon an early version of SDRC's Supertab software. This was partially a byproduct of a joint working relationship between the two companies in the late 1970s.

In April 1982, GST introduced the Autograph series, a lower cost single user system that also used the HP1000F. The company sold both low resolution monochromatic and high resolution color versions of these workstations which could be linked together using the IBM 2780 communications protocol. The black and white units sold for $79,000 including mechanical design and drafting software while the color unit

[26] *Computer-Aided Design Report*, October 1981, Pg. 9
[27] *The Low Cost CAD/CAM Systems Market*, International Data Corporation, May 1982, Pg. 39

was priced at $120,000. The NC software was particularly good and Gerber's systems were well accepted by customers doing tool and die production.

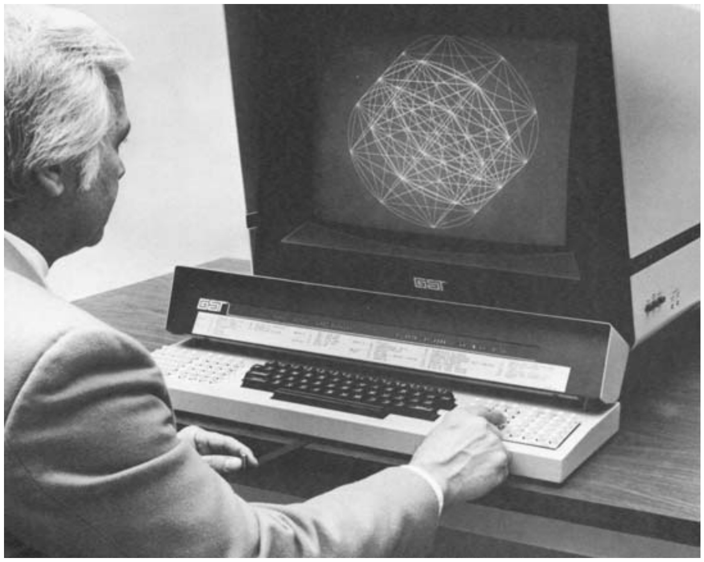

Figure 21.6
Gerber IDS-80 Storage Tube Terminal
(Note lever under keyboard used to control cursor and the two 40-button function keyboards bracketing the alphanumeric keyboard)

A sheet metal package developed by a user organization, Pako Corporation, was announced at AUTOFACT in November 1982 and began shipping a year later. This software, which sold for $16,800 on a IDS-80 system, unfolded a sheet metal part and automatically created a drawing with bend lines and dimensions in a single batch operation.

In April 1985, the company introduced a new system called the SABRE-5000. It was a 32-bit UNIX turnkey system that came in two versions. A low-end system was built around a Masscomp MC-500 computer, 2MB of memory, a Lexidata LEX 90 color 19-inch display with 1280 by 1024 resolution and a separate alphanumeric display. The high-end version used a Hewlett-Packard HP-9000 Series 500 computer with 3MB of memory. The Masscomp-based system, including IDS software, was $79,000 while the HP system was $98,000. Solids modeling, sheet metal design, FEA and NC software was available as options. At the time, GST was generating about $22 million in annual revenue or about 10 percent of Gerber Scientific's total.

The SABRE systems suffered from several problems. At a time when other turnkey vendors were switching to standard workstation platforms, Gerber decided to build its own, relatively expensive, workstation. Supporting both Masscomp and HP computers with relatively low volume of each added considerable expense to the company's R&D.

 

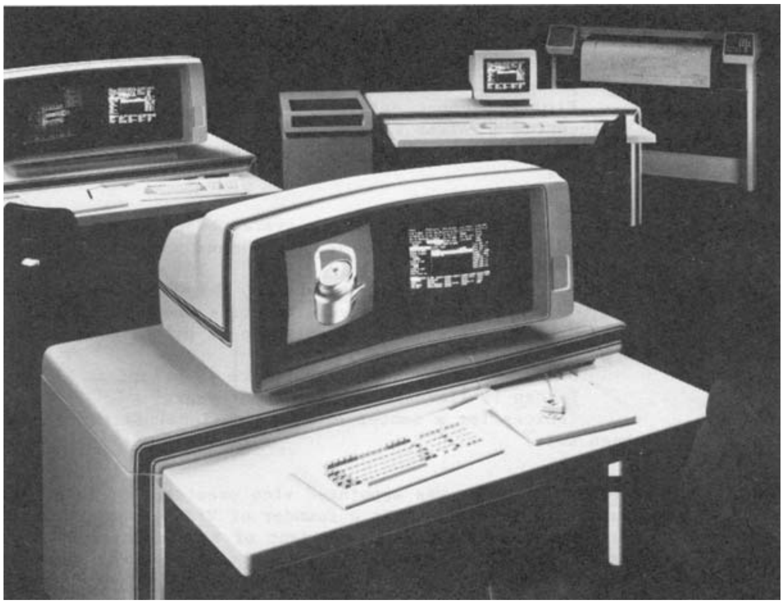

Figure 21.7
Gerber Systems Technology SABRE-5000

GST also marketed the SABRE-PC which included the Micro Control System's CADKEY software described earlier. These system sold for $25,000 which was far more than other PC-based CAD systems.

While the company was a serious contender for mechanical business in the early and mid 1980s, it seemed to loose momentum in the latter part of the decade. By 1990 the CAD business had faded away and this group began focusing on graphic design systems for the shoe industry. GST was then merged with Gerber Scientific Instrument to form Gerber Systems Corporation.

Although no longer in the CAD systems or software business, Gerber Scientific continues as a viable company. Revenue from 1985 through 1994 oscillated between about $200 million and $300 million. During the past ten years revenue has climbed to over $600 million while the company has a market value of only $250 million.

**GRAFTEK (Graphics Technology Corporation, Unisys CAD/CAM)**

GRAFTEK was formed in Boulder, Colorado in 1980 by a group of software developers and marketing people previously employed by Auto-trol Technology (see Chapter 9). The initial group included Jim Starnes, Ron McElhaney and Milan Marz although Starnes kept a fairly low profile due to a legal dispute with Auto-trol in regards to his leaving that company. Venture funding was provided by American Research and Development (the company that helped start Digital Equipment), Adler and Company and Jesse Aweida, the founder of Storage Technology Corporation.

While recruiting potential employees, McElhaney used the name "Sidney Greenstreet," an actor from the 1940s whose credits include a supporting role in "Casablanca." Among those recruited from Auto-trol were Dick Sowar who eventually became vice president of research and development and Chad Alber.

Sowar was the key hire in that he had a strong background in both software architecture and graphics. Although he never completed all the requirements for a Ph.D., his thesis subject was “Parametric Design in a CAD/CAM Environment.” This was nearly six years before Sam Geisberg began the development of Pro/ENGINEER at PTC.

Like most companies in the CAD industry in the early 1980s, their business plan was based on both building graphics hardware and developing application software. The company’s first workstation was the Meteor introduced in 1981. This was followed by the Meteor II in April 1985 that included a 19-inch 16-color monitor (expandable to 256 colors) with 1024 by 768 resolution and an optional graphics processor capable of handling local three-dimensional rotations as well as dynamic pan and zoom. The Meteor II could be used as a terminal for 32-bit minicomputers from Hewlett-Packard, Digital Equipment and Systems Engineering Laboratories with the SEL system being the company’s preferred platform.

The company’s primary software was GMS (Geometric Modeling Software). It was a three-dimensional wireframe and surface modeling package that used commands entered via a keyboard, function keypad or data tablet. GMS was based on MCS’ AD-2000 which was a logical move considering that McElhaney had worked for MCS before joining Auto-trol and that at Auto-trol he had been responsible for implementing AD-2000 for that company. Up to 20 different views of a model could be generated and selectively displayed. The drafting software included a library of “intelligent symbols” that could be placed, oriented and sized in drawings.

GMS was complemented by analysis software, a graphics programming language called AGILE (Algorithmic Graphic Interface Language), finite element modeling software and NC software capable of handling 5-axis machine tools. A third party injection molding analysis package, OptiMold from Optimold Limited of England, was also available from the company as was a solids package, Romulus, developed by Shape Data, a subsidiary of Evans & Sutherland located in England. Eventually, GRAFTEK became Shape Data’s largest OEM customer. Customers tended to be companies needing mechanical design and NC operations, particularly in the tool and die industry.

While the company’s software was well regarded within it target markets, GRAFTEK never built up the sales momentum to be considered a serious player in this industry. By 1983 it was obvious that the company was struggling and the company’s investors hired Cy Lynch as the new CEO. It was then acquired by Burroughs Corporation in 1984 for $23 million. Shortly thereafter, Lynch resigned from the company to return to Texas and Burroughs brought in Stanley Eaton as the new CEO. Sowar stayed with GRAFTEK until 1986 at which time he left to start Spatial Technology. At its peak, the company probably had about 60 or 70 employees.

A number of GRAFTEK’s developers led by Ron McElhaney left at that point and formed UNICAD with the intent of creating a software development platform that could be used to build either proprietary or commercial CAD software. He was joined by Bert Hertzog, a graphics industry pioneer and the former head of the University of Colorado Computer Center. Evans & Sutherland was a major investor in this new endeavor. UNICAD never gained much traction and McElhaney subsequently went to work for Autodesk.

In 1986, Burroughs and Sperry merged to form Unisys Corporation and GRAFTEK became Unisys CAD/CAM. In early 1992 GRAFTEK was acquired from

Unisys Corporation by Gores Group[28] (Gores subsequently acquired Applicon as described in Chapter 7) which operated the company until it was sold to C-Tech, an Austrian distributor in 1996. C-Tech set up a subsidiary in Boulder, C-Solutions, that continues to maintain and support GRAFTEK's GMS software now called GMSWorks.

**Information Displays Incorporated (IDI)**

Information Displays, Inc. (IDI) was one of the earliest vendors of commercial graphics hardware. Founded in 1960, the company manufactured a product line of vector refresh displays. I worked with IDI from 1965 to 1969 developing a graphics system used to control refinery operations at Lago Oil and Transport, an Exxon subsidiary, in Aruba, Netherlands Antilles. The executive vice president of IDI at that time was Carl Machover, a well respected industry pioneer and consultant.

In 1975, IDI was acquired by a Bennet LeBow, who would make an attempt to take over Prime Computer 13 years later. LeBow installed Dr. William Weksel as president and IDI switched its focus to turnkey CAD systems. Its primary product was known as the System 150 and the software, itself, as IDRAW. While IDRAW was primarily sold to AEC users, a separate version called Graphic Design/Illustrator (GDI) was sold to organizations doing technical illustrations. GDI subsequently was renamed ICAPS.

The IDRAW software had more flexibility for creating line art than most contemporary systems. It could shade lines, inset broken dimension lines, create drawings in dimetric or trimetric projections and handle multiple fonts. Line weights were display by adjusting the intensity with which the lines were displayed. Overall, the GDI/ICAPS system contained many features that are routine today but were fairly novel in 1980.

The system used a Sperry-Univac V77-600 16-bit minicomputer that supported four IDI displays. A basic system had just 32KB of memory and a 40 or 80MB disk drive although a 300MB unit with a removal cartridge was also available. This was the same hardware configuration used by Auto-trol Technology in its early systems. A single workstation system cost $150,000 while a four-seat configuration went for $300,000.

IDI also took a business-like approach to financing its systems. You could lease a system for 5% of the purchase price per month with 50% of your payments going towards subsequent purchase. The company also offered a $200 per day rebate if your system was inoperable.

IDI began loosing momentum in the early 1980s. In 1983, the company lost $7 million on revenues of just $10 million. In January 1983, IDI introduced a technical illustration system, CADalyst, that incorporated a new workstation built by the company along with the ICAPS software. The system was plagued with problems and never worked properly. In March 1984, control of the company was taken over by a group of investors led by Leonard Levy who immediately stop production of CADalyst systems and reduced the company's employment from 185 to about 100.

Levy and his partners had purchased shares of IDI on margin and as IDI's stock price dropped, they were unable or unwilling to meet margin calls. IDI filed for Chapter 11 bankruptcy in May 1984. In early 1985, the bankruptcy court changed this to a chapter 7 liquidation and the company's remaining assets were sold off in a series of auctions.

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[28] *Computer Aided Design Report*, March 1992, Pg.15

 

**IronCAD (3D/EYE, Visionary Design Systems, Alventive)**

IronCAD's roots go back to a company called 3D/EYE founded in 1981 by Dr. Donald Greenberg and Dr. John Abel, both of whom were associated with the Program for Computer Graphics at Cornell University. At the time, Cornell was one of the leading graphics research centers in the world. 3D/EYE was established to give Greenberg and Abel and their students a vehicle for developing commercial computer solutions.

One of the first such products was a structural steel design and analysis program called STEEL 3D, developed for Auto-trol Technology (See Chapter 9). For the first 12 or so years of the company's existence, 3D/EYE functioned as a technology boutique doing graphics software work for companies such as Hewlett-Packard. In the mid-1990s, Dr. Samir Hanna, who had been with 3D/EYE since the STEEL 3D days, realized that it was becoming feasible to develop low cost 3D modeling and visualization products that could be used by both professionals and non-professionals. The two enabling technologies were:

1. Functionally rich PC operating systems such as Windows 95 and Windows NT which incorporated much of the "house keeping" functionality that previously application programmers had to develop and maintain.

2. Solution vendors no longer had to develop entire products by themselves. Modular components such as geometric modeling engines could be licensed at reasonable costs. In this case, 3D/EYE decided to work with Spatial Technology and incorporated the ACIS geometric kernel into its packages.

In April 1995 3D/EYE, which by now was located in Atlanta, Georgia, got Paul Allen, the co-founder of Microsoft, to purchase a minority equity position in the company through Allen's Vulcan Ventures investment firm. In October 1995, the company began shipping two revolutionary new products, TriSpectives and TriSpectives Professional. The software used a method of building three-dimensional models by dragging and dropping pre-made parametric shapes called IntelliShapes and then subsequently interactively refining them. Users could also build model element using traditional sketching and extrusion techniques. The packages sold for between $300 and $500, far less than SolidWorks or Solid Edge.

3D/EYE started a rather aggressive marketing campaign quoting Evan Yares as saying that TriSpectives was a "Pro/ENGINEER killer" – a statement Yares denies making as quoted. While it was not a replacement for traditional CAD software, TriSpectives was an excellent conceptual design tool. Although a large number of copies of this software were sold, sales did not live up to expectations and in March 1997, the TriSpectives technology was acquired by Visionary Design Systems of Palo Alto, California. Visionary Design Systems (VDS) was founded by David Tiley, a former Hewlett-Packard salesman. Its primary business at the time was reselling CoCreate software described earlier. The 3D/EYE development staff including Samir Hanna stayed in Atlanta. A new version of the software, TriSpectives Technical, was released later that year priced around $1,000.

At the National Design Engineering Show in Chicago in March 1998, VDS introduced a new product that was closer to being a full-function CAD system. Called IronCAD, it was based on the TriSpectives foundation but included more comprehensive geometric modeling capabilities. It had a list price of $3,995 and began shipping that June. *Engineering Automation Report* was suitably impressed:

 

> "In developing IronCAD, VDS retained and improved upon much of TriSpectives' ease-of-use but added real geometric modeling under the covers. The underlying method for building geometry is very powerful and unlike any other package on the market. This is probably the easiest program to rapidly develop geometry; it really has to be seen to be appreciated."[29]

By late 1999, IronCAD 3.1 was being shipped with a list price of $4,995. It was one of the first packages that used both Spatial Technology's ACIS geometric kernel as well as UGS' Parasolid. The result was improved interoperability with other software packages. The key aspect of the software was that used a combination of explicit modeling such as CoCreate's SolidDesigner as well as history-based parametric modeling used by Pro/ENGINEER, SolidWorks and others.

Eventually, VDS changed its name to Alventive then in March 2001 it spun off the IronCAD activity as a separate employee-owned Atlanta-based company also called IronCAD. The company subsequently continued to enhance this software with IronCAD 9.0 released in June 2006. Alventive it self was eventually acquired by BlueSky Solutions in 2004.

**ISICAD (Personal CAD Systems, FIT)**

CADVANCE was introduced in 1982 as CADplan by Personal CAD Systems (P-CAD) of San Jose, California. The company's drafting software business was acquired by the CalComp division of Sanders Associates in March 1985 for $7.5 million and renamed CADVANCE. As described above, CalComp's CAD systems business unit was sold in 1987 to ISICAD, GmbH of Ellwangen, Germany, a wholly owned subsidiary of ISI-MAT, a machine tool manufacturer. A new company, ISICAD, Inc. was established in California to market the software acquired from CalComp. Under ISICAD, CADVANCE software sold for $3,295. The initial head of this operation was John Arnold who had spent 18 years with CalComp, most recently as director of product development for the Systems Division.

The CADVANCE software was sold primarily for architectural and facility management tasks. The company also launched a solids modeling package called Solid Vision and a Motorola 68020-based workstation, the PRISMA. Neither of these latter two products ever seemed to achieve much sales momentum.

CADVANCE used an integer data structure that resulted in relatively fast graphic operations without the need for a graphic accelerator. The software also worked directly with Ashton-Tate's dBase database management system. CADVANCE 5, released in 1992, was one of the first CAD packages adapted to the Windows operating system, initially for Windows 3.1. Over the years, the software has predominately been used for architectural design and drafting. Users have historically liked its ease of use and the ability to rapidly train new users.

Among the key executives in the early 1990s was Yoav Etiel who was later hired by Bentley Systems as its vice president of marketing. Over the next few years, ISICAD struggled to compete against AutoCAD and MicroStation. In 1995, Furukawa

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[29] *Engineering Automation Report*, April, 1998, Pg. 2

Information Technology (F I T) was established by Takashi Furukawa and John Milius in Anaheim, California for the express purpose of acquiring ISICAD. Both had previously worked for CalComp. For the next decade, F I T continued to expand the capabilities of CADVANCE and to market it in a relatively low-key manner.

By 2006, CADVANCE 12 was being shipped at a list price of $1,995. A CADVANCE LiTe version of CADVANCE 12 was also available $495. The software was sold directly by the company and through a small group of domestic and international dealers. The company also offered CADVANCE 6.5 which was developed for Windows 3.1 but also runs on Windows 95/98 and NT systems. It was available as a free download from FIT's web site for users who were using these older operating systems. In mid-2004, over 700 copies of this free version were being downloaded monthly.

**Matra Datavision**

If this book were being written in Europe, Matra Datavision would undoubtedly deserve an entire chapter. Its impact in the United States was relatively limited, however, and, therefore, it has been relegated to this chapter.

Matra Datavision was the CAD/CAM division of Matra, a broad-based French industrial concern with defense and aerospace operations in the United States. The company's flagship product was a solids-based CAD/CAM package called EUCLID-IS where the IS stood for Integral Solution. It was initially developed at the French National Center for Scientific Research in the 1970s as a batch-oriented computer programming language and was used on projects such as the Concorde supersonic transport. A company called Datavision was formed to commercialize this technology. The software implemented a boundary representation solid modeler with tessellated surfaces. This latter feature resulted in fairly rapid display of shaded surfaces and hidden line views of solid models once the software began using interactive graphics.

One early customer was the aerospace division of Matra. They liked the product so much that they bought the company in 1980 and renamed it Matra Datavision. In 1981, a U. S. operation was set up in Burlington, Massachusetts, partially owned by Matra and partially owned by the employees. While the European version of the software had been implemented on IBM mainframes, the U.S. version ran on Digital VAX computers using Tektronix displays. The VAX version of the software was licensed for $120,000 to $140,000 depending upon the options selected. Tektronix display terminals were about $15,000 each while a VAX systems capable of supporting eight EUCLID users cost over $550,000.[30]

The company also had an agreement with IBM to resell IBM 4300 computers and 5080 graphic displays running EUCLID but as far as I can tell, this never resulted in any significant number of installations in North America. Like most other CAD vendors in the early 1980s, Matra Datavision also designed and manufactured its own graphics terminals. By 1987 the company shipped over 2,000 of these terminals.

Matra Datavision had a strong relationship with Renault dating back to 1984. A number of technical advances in EUCLID including improved surface geometry and NC machining functions came from Renault under this agreement. Renault subsequently

[30] *Computer Aided Design Report*, May 1982, Pg. 6

purchased about a quarter of the company and in 1989 its development staff was merged with Matra Datavision's at a new facility in Les Ulis, France.

In 1988, the company signed an agreement with Digital under which the latter firm became a major distributor of EUCLID systems. This adversely impacted the company's relationship with other computer manufacturers and eventually it was terminated. Matra Datavision had tailored a number of functions specifically for the Digital hardware and this tended to defocus the company's development efforts for several years.

EUCLID-IS was built around a solids modeler that combined boundary representation and constructive solids geometry techniques as well as an object-oriented database. In many regards, EUCLID-IS was one of the most advanced CAD systems on the market in the early 1990s. Unfortunately, the company was never able to match its technology with effective marketing. The EUCLID-IS software consisted of about 30 modules. A basic system started at around $10,000 with typical software configurations selling for about twice that. Matra Datavision used a combination of direct sales and dealers. The latter became important when the company introduced a lower-cost system in North America called Prelude/Solids in 1992 which sold for $3,995 and was initially available on Sun and SGI UNIX workstations.

Also in the early 1990s, the company began working on a new development environment called CAS:CADE. It was a C++ tool set that was planned to be used for both internal development and to be licensed to independent developers.

Matra merged with communications giant Hanchette in 1993. Hanchette published magazines such as *Road & Track* and together with Matra was an $11 billion enterprise of which Matra Datavision was probably a $100 million piece. The parent corporation was subsequently renamed the Lagardère Groupe. Also in 1993, the company launched a PC-based design and manufacturing package called PRELUDE.

By mid-1994, the software was being called EUCLID 3 and the company was supporting a variety of UNIX workstations as well as Digital VAX/VMS systems. The primary workstations being used by customers were those manufactured by Silicon Graphics. In 1994 the company acquired Cisigraph and its STRIM styling and surface geometry software. Within two years, Matra Datavision was doing $160 million worldwide and growing 30 percent annually. By then, the company had 18,500 seats of its software installed at 4,700 customer sites. Its North American business, however, never got much above $15 million annually. The company had 720 employees and its chairman and CEO was Michel Neuve Eglise while the president and COO was Hugues Rougier.

In late 1996, Matra Datavision introduced a new CAD/CAM system called EUCLID QUANTUM that used CAS:CADE as the development environment. It had a very attractive user interface, used object-oriented software technology extensively, incorporated a STEP-compliant data model and contained a broad suite of applications. The basic mechanical design software had an initial list price of $14,900 in the United States. Unfortunately, the execution of this new system did not match the fanfare with which it was introduced and the company's market position began to slowly deteriorate.

On February 24, 1999, Dassault Systèmes announced that it had completed the acquisition Matra Datavision's styling software products including EUCLID STYLER, EUCLID MACHINIST, STRIM and STRIMFLOW as well as a license to use the

 

CAS:CADE development tool set for FF 200 million. The intent was to integrate this software into CATIA Version 5. While Matra Datavision retained ownership of the basic EUCLID product, the plan was that while it would support existing users, the company would not solicit additional customers.

Matra signed a separate agreement with IBM to become a reseller and system integrator of Dassault software including CATIA and ENOVIA. The expectation at the time was that Matra would encourage its customers to migrate to CATIA V5. The company was subsequently renamed MDTVISION and continues as a consulting and service company supporting IBM PLM solutions.

**Spatial Technology (PlanetCAD)**

Spatial Technology was founded in Boulder, Colorado in 1986 by Dick Sowar, who had previously been vice president of research and technology at GRAFTEK. The initial product plan was to develop NC software that worked directly on solid models. Sowar felt that it was a step backwards to build a part model using solids and then reduce the model to its surface representation in order to generate NC tool paths.

The initial funding for Spatial was provided by Fred Nazem who had also been one of the early GRAFTEK investors. He invested $1 million in the company and placed Cy Lynch, who had been CEO of GRAFTEK, as CEO of Spatial with Sowar as CTO. The company formally started functioning in September 1986. The first order of business was to license a solids modeler that could serve as the base for the applications the company planned to develop. Sowar spoke to a number of potential providers including Dave Albert at Vulcan Systems, Peter Veenman at Shape Data and even Sam Geisberg at PTC.

None of these contacts proved fruitful and Sowar and Lynch eventually met in London with the principals of Three-Space Ltd., located in Cambridge, England. Three-Space was headed by Ian Braid and consisted simply of himself along with Charles Lang and Alan Grayer – thus the Three in Three-Space. They had earlier been involved in the development of BUILD I, BUILD II and ROMULUS solids modelers as well as the definition of what eventually became Shape Data's Parasolid. They agreed to create a solids package for Spatial on the understanding that Spatial would turn it into a marketable product.

The NC software was known as Strata which continued as a Spatial product until around 1992. It was the solids modeling component technology, however, that quickly became the company's focus of attention. Rather than trying to become just another CAD vendor with some neat technology, Sowar decided that there was a significant future in selling component solids modeling technology that others could use to develop end-user applications not necessarily limited to CAD products. Spatial worked with a number of other firms to create a more complete product offering. These partners included Lightworks Design which provided photo-realistic rendering and D-Cubed which provided constraint management software. In fact, Spatial provided the seed money that enabled John Owen to start D-Cubed, a developer of constraint management software.

Meanwhile, Spatial continued to work on Strata. One substantial project involved porting Strata to work with SDRC's GEOMOD solids modeling package. SDRC paid Spatial $1.5 million for this work.

 

Although Lynch was CEO, he never moved to Colorado and continued to operate from his home in Texas visiting Boulder every few weeks. In 1987 he was replaced as CEO by Fred Schumacher who had previously been with Control Data Corporation. He was also recruited by Fred Nazem. Schumacher never fit in at Spatial and left within a year.

A search firm then introduced John Rowley to the company and he was hired as president and CEO in 1988. Rowley was an extremely high-energy individual who had previously been with Tektronix, Intel and Digital Research.[31] Around this time the geometric kernel became known as ACIS.[32] This core software component, written in C++, was introduced in 1989. By this point, Nazem alone had invested $4.4 million in the company. This was an unusually situation since, typically, most high tech startups have multiple venture capital firms funding them.

Fairly soon after deciding to market ACIS as component technology the company signed Hewlett-Packard’s Mechanical Design Division as an ACIS licensee and HP purchased a 10 percent interest in the company as part of a $7 million private placement. Other investors included Union Carbide and Allied Signal, both potential users. Fairly soon thereafter Spatial signed Control Data and Autodesk as licensees as well as about ten other firms.

The typical contract called for an initial license fee plus royalties for each application package sold based upon the value of that package. The first contract with Autodesk called for a royalty of $25 per copy of AutoCAD. At the time, Ron McElhany, who had worked with Sowar at GRAFTEK, was Autodesk’s vice president of R&D. Autodesk subsequently asked to renegotiate its agreement with Spatial and sent Len Rand to discuss the situation with Rowley. The two got into an argument over the coming importance of Microsoft’s Windows NT and negotiation broke down. Autodesk subsequently announced publicly that it was looking at alternative strategies.

A key marketing executive until 1996 was Bruce Morgan who, after a stint as ANSYS, would return in 1999 as the company’s president and COO. Morgan was able to get Autodesk back to the table in 1991 at which time they negotiated a new agreement that provided Autodesk with the option of paying $6 per software package or a flat $1 million per year. ACIS was initially used in AutoCAD beginning with Release 13 and eventually became core technology for Autodesk’s Inventor mechanical design package. Until it decided to go its own way a decade later, Autodesk routinely paid the $1 million each year.

While Three-Space developed the basic ACIS geometric kernel, other software was need to flesh out the product. Spatial called these additional modules “husks.” An example was a NURBS surface geometry husk that was being developed by Bob Blomgren at Applied Geometry Corporation in Seattle, Washington. Other husks included software for turning solid objects into thin-shell models, generating shaded images, constraint management, finite element modeling and translators to other data formats. A key feature of ACIS was its import/export format called SAT (Save As Text)

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[31] Rowley hired me at Tektronix in 1975 to be director of market development for the company’s Graphic Systems Division.

[32] The first three letters of ACIS represent the three principals of Three-Space Ltd. while the S stands for Spatial.

 

that the company published for use by other software developers. ACIS was available for a variety of UNIX platforms as well as PCs running MS/DOS.

For several years, Spatial ran a periodic technical meeting called TECH-EX for licensees and other interested industry participants. The first was in Detroit in 1991 at AUTOFACT, while the next was in Berlin in 1992, then Boca Raton, Florida in 1994 and New Orleans, Louisiana in 1996. One purpose was to promote a user organization called ACIS Open that in addition to Aries and HP included companies such as Digital, Ford and Mercedes-Benz.

Rowley's relationship with the company's major investors deteriorated starting around 1991 and he left the company in 1993. Sowar became CEO while continuing as chief technical officer. Chuck Bay, who had previously worked for Steve Jobs at NeXT Computer and was Spatial's CFO, became the company's COO. The company seemed to be riding high. Bentley Systems, SolidWorks and Intergraph were all developing packages using ACIS.

The concept of component software technology was now an accepted strategy in the CAD industry. Jerry Sisson, who had joined the company in a sales management role, became president and COO when Bay left to return to California in 1994. Ron Belcher was vice president of development. Overall, the company appeared to have a fairly strong management team.

Spatial gradually moved from being a marketing company that packaged software developed by others to more of a development company although it was still dependent on other firms for much of the software it licensed. Also, it was taking longer for these licensees to bring products to market than originally expected. Since Spatial's business model was predicated on royalty revenue from each package sold, the company struggled to generate enough revenue to kept extending ACIS as its customers were requesting. One problem was that end user packages such as Bentley's MicroStation Modeler demonstrated very well, as long as known problems with ACIS were avoided. End users, however, needed bullet-proof software and ACIS was not yet there.

To facilitate application development, Spatial introduced the ACIS 3D Toolkit in 1994. In addition to ACIS, it included a set of kernel extensions and a development language based on Scheme, a LISP-like scripting language used extensively as an educational tool. By mid-1996 ACIS based software was shipping from Autodesk, Intergraph, 3D/EYE, Applicon and Bentley as well as many point solution vendors. Overall, the company claimed that it had more than 350 licensees who were shipping nearly 60 commercial products.

ACIS 2.0 incorporated improved surface blending, deformable surfaces, the healing of imported geometry and shelling. The latter software was developed by an Indian software firm, Godrej and Boyce, subsequently known as GSSL and now known as Geometric. One major problem was that HP was no longer using new ACIS releases but was making its own extensions to the initial ACIS code it had used in SolidDesigner. Things were going well enough, however, that Spatial went public in October 1996. Morgan, who had left to join ANSYS in 1996, returned in July 1997 as president and COO. ACIS 3.0 was released in mid-1997.

In late 1997, Spatial was hit with the defection of several key customers including Bentley Systems and Intergraph who announced they were switching to UGS' Parasolid software. Their complaints centered on a combination of functionality and performance issues. In addition, Computervision selected Parasolid for its new DesignWave package. Spatial worked hard to respond to these defections. ACIS 4.0 was released in mid-1998. While there were a number of functional enhancements in areas such as surface blending and lofting, the major focus was improved performance and software reliability. Many tasks were done 40 percent to several hundred percent faster than with ACIS 3.0.

Over the next several years Spatial made a number of acquisitions, especially in the area of data translation and viewing including InterDATA Access, Inc. In addition, Spatial acquired Three-Space, Ltd. and its founders became Spatial employees. The InterDATA acquisition and several licensing agreements with other companies led to an interoperability product called 3D ModelServer and a web-based service called 3Dmodelserver.com introduced in 1999. The latter product was soon renamed 3Dshare.com. The intent was that customers would submit models to Spatial and for a fee based on the model's size, Spatial would translate and heal the data. Initially, I was very excited about this business concept. Unfortunately, the software never lived up to the hype. Spatial's revenue peaked in 1999 at $14.9 million but the company lost $2.9 million due to investment in its new on-line services. It was running through the cash raised in its public offering at an alarming rate.

By early 2000, Spatial was focused on two business activities, its software component business which produced the bulk of the company's revenue and an emerging business of providing data translation and other services on the Internet. The latter services were dubbed PlanetCAD. In August 2000, Spatial agreed to sell its software component business to Dassault Systèmes for $25 million. (After various fees and reimbursement of loans from Dassault, the net was only $17.4 million.) Dassault was not the only CAD company interested in ACIS. SDRC also made an offer worth about $25 million.

The deal with Dassault closed in November 2000. Dassault retained the Spatial name and the remainder of the company was renamed PlanetCAD with Bruce Morgan as CEO. A key part of the new PlanetCAD was software obtained when Spatial acquired Prescient Technologies in July 2000. Prescient, formerly a division of Stone & Webster, was the developer of software that could be used to verify the integrity of mechanical models. This software was marketed by PlanetCAD as Prescient QA.

Dassault continued to operate Spatial as a vendor of geometric kernel technology under the management of Michael Payne, one of the founders of SolidWorks. Interestingly, seven years later, SolidWorks, another Dassault subsidiary, still used Parasolid as its primary geometric kernel. Keith Mountain, who had earlier worked for Computervision, joined Spatial as vice president of marketing in May 2002 and became president and COO in 2004. He replaced Payne as CEO in 2005 Payne left Dassault and started a new company, SpaceClaim, in Concord, Massachusetts that is currently developing three-dimensional modeling software.

PlanetCAD struggled from the start. The company attempted to market a number of on-line services including model quality assurance (also sold as stand-alone software), CAD data translation and healing and rapid prototype cost estimating without much success. Morgan left the company in late 2000 and was replaced by Jim Bracking, who had headed several other high tech companies but none in the engineering software field. In 2001 PlanetCAD had revenues of $1.8 million and lost $12.4 million. Sowar left the company in October 2001 and in January 2002 Bracking was replaced as CEO by David

 

Hushbeck. Sowar subsequently started another company focused on geometry creation called FreeDesign.

The end of the line for PlanetCAD came in November 2002 when the company was merged with Avatech Solutions, a major reseller of Autodesk software. The intent from Avatech's position was to gain access to the several million dollars in cash PlanetCAD still had and to have its stock listed on the American Stock Exchange by taking advantage of PlanetCAD's listing. PlanetCAD's products were of secondary interest. Avatech's stockholders ended up owning 75 percent of the company which retained the Avatech Solutions name while PlanetCAD's stockholders received 25 percent.

Avatech split PrescientQA into two products, one version which is still called PrescientQA for high-end systems such as Pro/ENGINEER and CATIA and a separate version called Proof Positive for mid-range systems such as Autodesk's Inventor. PrescientQA was sold to European-based TDCi in 2003 while Proof Positive was sold to Autodesk in 2005.

**think3 (CAD.Lab)**

CAD.Lab was started in 1979 in Bologna, Italy by Filippo Zuccarello to offer two-dimension drafting software. By 1997, the company had sold over 10,000 copies of its software to about 2,500 customers, mostly in Italy and had about $34 million in annual revenues. CAD.Lab had also developed a full-function Windows-based solids modeling package called Eureka Gold 97 that incorporated a proprietary geometric modeling kernel.

Zuccarello intended to become a worldwide player in the mechanical CAD market and to do so, he believed he had to relocate to the United States. The company set up a new corporate headquarters in Santa Clara, California in 1997, raised $7 million in new financing from U.S. Venture Partners and hired Joe DeNucci away from SGI to be the company's president with Zuccarello remaining as CEO. DeNucci lasted just a few months and was gone before the year was over.

Eureka Gold had a clean user interface and easily combined surface defined geometry with solid models. The initial expectation was that this package would sell well to stylists and industrial designers competing against SolidWorks, Solid Edge and Autodesk Mechanical Desktop. The major problem was the fact that at $12,000, it was priced more like Pro/ENGINEER than the products it was most likely to be compared to. When all the functionality included in Eureka Gold was added to other mid-range packages, usually via third party products, the gap narrowed considerably but that was not the way potential users viewed the situation.

In early February 1998 CAD.Lab surprised nearly everyone by naming Joe Costello as chairman and managing director. Costello had been CEO at Cadence Design Systems until 1997 when he resigned and was considered by some as a potential CEO at either Apple or SGI, both of which were looking for new leaders at the time. Costello is a high-energy executive with an imposing physical presence. Although Zuccarello retained the CEO title it was obvious fairly quickly that Costello was really running the company. He was not shy of criticizing competitors and was extremely optimistic about the company's prospects. He stated in public that the mechanical CAD industry was stagnant and there had been little innovation for over a decade. In November he was formally named CEO.

Costello felt from the start that CAD.Lab offered high end CAD capabilities at a mid range price. That fall he decided to hold a contest to find a new name for the company. For a while CAD.Lab was known (seriously) as The Company Formerly Known as CAD.Lab. By December 1998 the company received over 40,000 entries from around the world. The winner of the $50,000 prize with his suggestion of “think3” was an Italian, Fabio Orsi. The company began calling itself “the mechanical design upstart” and referring to Costello as a “Silicon Valley icon and technopreneur.”

In March 1999, think3 launched a new product line consisting primarily of thinkdesign, a three-dimension wireframe, surface geometry and solids modeling package and thinkshape which added extensive surface geometry capabilities to thinkdesign. The target market was clearly that of moving two-dimensional users of AutoCAD to three-dimensional modeling. Rather than selling fully paid licenses, the company initiated an annual subscription model. Including software maintenance and technical support, thinkdesign cost $1,995 annually while thinkshape was $2,995. Richard Cuneo, who was instrumental in developing Autodesk’s reseller channel was hired to do the same for think3. A visualization module, thinkreal, based on software from LightWork Design, cost an additional $350 annually.

think3 placed substantial effort into developing new techniques for training thinkdesign users, especially those who were making the transition from two-dimensional AutoCAD drafting to three-dimensional modeling. The tutorials gave designers an interesting combination of gaming, video demonstrations, and step-by-step instructions for using the actual CAD system to perform tasks. The gaming portion – "The Monkey Wrench Conspiracy" –involved a level of violence more associated with the then popular game Doom. In the course of killing violent enemies, the game required users to repair necessary items by designing replacements or performing other actions that taught solid modeling skills.

In September 1999, Costello personally took over worldwide sales replacing Cuneo. The company began selling its software on the Web at this point. A month later the company launched thinkdesign 4.0 with improved drafting and part library capabilities. During the second half of 1999 the company signed up over 3,000 thinkdesign subscribers. In March 2000 the company announced that it had closed a third round of financing for $20 million. This was on top of the $18.5 million it had raised in 1988, shortly after Costello joined the company.

Like most other companies in the CAD industry, think3 revenue growth slowed with the recession during the early part of the 2000s. There were personnel cutbacks, a switch from focusing on industrial design to machine design and a relocation of the company’s headquarters from Pleasanton, California to Cincinnati, Ohio. The company’s business did continue to grow, however, with revenues of $40 million in 2004. Costello is no longer involved in running the company’s operations but is still chairman of the board. Zuccarello is once again CEO while Fabrizio Giudici is COO. Most of the software development continues to be done in Italy and India.

**Unicad**[33]

Unicad is significant in that it was one of the first companies to offer component software that other organizations could use to create engineering design and analysis applications that were not available from traditional CAD vendors. The company was founded in March 1983 by Dr. Ronald McElhaney and Dr. Bert Herzog with funding from Evans & Sutherland Computer Corporation.

McElhaney had been in charge of Auto-trol Technology's mechanical CAD software development activity in the late 1970s. He left Auto-trol in early 1980 to join GRAFTEK as one of that company's founders. Herzog had been involved with computer graphics since 1963 and was a former professor of computer science at the University of Michigan and the University of Colorado. He was also instrumental in the establishment of SIGGRAPH.[34] Other early employees involved in software development included David Prawel, Chad Alber, Griff Hamlin, Doug Hakala and Phillip Poirier. Dan Woods and Brian Doyle joined about a year later to handle sales and marketing for the company.

The company initial planned to offer a graphics software environment called the Universal CAD System that other companies could use to create CAD applications. Hence the name Unicad. The company's intent was to provide a software toolkit that would handle graphical user interface issues (using a PHIGS library), database management (primarily using Sybase) and geometric modeling including the Romulus solids modeler which was property of E&S at the time.

The initial version of the company's software was released in late 1984. The target market consisted of companies that wanted to implement specialized graphics applications that were not readily available from traditional software vendors. Early licensees included Westinghouse and the National Bureau of Standards. The latter organization planned to use the software in its Automated Manufacturing Research Facility. According to Prawel, in nine months they had written over 300,000 lines of code. Unfortunately, the rush to demonstrate a complete set of development tools resulted in some relatively unstable software. He describes McElhaney as a brilliant technologist who was always pushing the envelope. As an example, as the programmers were trying to complete programs written in C, he wanted them to begin the transition to C++ which was a relatively untested programming language at the time.[35]

In late 1985 Unicad announced that it would offer a pair of CAD systems itself. Unicad DD/1 (Design-Drafting/1) was to be a three-dimensional wireframe design and drafting system. Unicad M/P/E (Modifiable/Portable/Extendable) incorporated the same user interface as DD/1 plus surface geometry and an optional solid modeling module. The concept was that customers would be able to use the Unicad tool set to modify the basic system to meet their specific requirements. About this time, both McElhaney and Herzog left Unicad and Jose Villalobos took over as president and CEO. McElhaney went to work for Autodesk where he became vice president of technology while Herzog joined Fraunhofer Center for Research in Computer Graphics in Providence, Rhode Island.

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[33] There are several other products and companies that use the UNICAD name in some form. This section specifically refers to UNICAD of Boulder, CO established in 1983.

[34] SIGGRAPH is the Special Interest Group for Graphics of the Association of Computing Machinery (ACM)

[35] Interview with David Prawel, July 19, 2006

For the next several years UNICAD tried to gain traction without much success. In addition to Westinghouse, other key accounts included Framatome, the French nuclear engineering firm, and Jonathan Corporation, a naval defense contractor in Norfolk, Virginia. One of the major problems the company faced was that nearly every one of its customers wanted the software ported to a different UNIX platforms. In 1987 UNICAD's investors pushed the firms management to find a buyer for the company. Eventually Jonathan Corporation bought the company and moved the operation to Norfolk. Only a few of UNICAD's technical staff made the move. Many of the others ended up working at Spatial Technology with Dick Sowar. Jonathan primarily used the software for internal projects and eventually the UNICAD technology as well as Jonathan simply faded away.

**Visio (Axon, Shapeware, IntelliCADD, Boomerang Technology, IntelliCAD Technology Consortium)**

Visio was founded in Seattle in September 1990 as Axon Corporation by Jeremy Jaech (president), Ted Johnson (vice president, product development) and Dave Walter (chief architect). All three had previously been employed by Aldus Corporation where they worked on the development of PageMaker. The name was changed in 1992 to Shapeware, about the same time that its first product, Visio 1.0, began shipping.

The focus was on what the company called "business diagramming." Visio created "drag-and-drop" pre-drawn shapes called SmartShapes. Users were able to quickly create diagrams such as flowcharts, organization charts, network diagrams and other non-dimensioned drawings using these pre-constructed shapes and connectors. The company changed its name to Visio Corporation and went public in 1995. This initial version of Visio subsequently evolved into a product called Visio Standard.

By mid-1997 Visio Technical, an improved version of Visio Standard, provided considerable capabilities for a package that routinely sold for less than $300. Running on a PC that cost about $3,000, it was capable of handling basic drafting tasks such as electrical diagrams that a decade earlier required CAD systems costing over $50,000 per seat. Visio Technical's symbol library contained over 3,800 SmartShapes. About this same time, Visio also introduced Visio Maps, a GIS application built on top of the underlying Visio technology. Other versions of the basic Visio software were released in 1997 and 1998 with list prices for the product line ranging from $129 to $995.

As described in Chapter 8, Softdesk had acquired a company in San Diego, California called IntelliCADD in 1994. Shortly thereafter, IntelliCAD began developing an database and command clone of AutoCAD called Phoenix. After several years of effort, Softdesk decided to suspend development and a number of the developers set up a company called Boomerang Technology with the intent of acquiring the Phoenix technology from Softdesk.

At about the same time, Autodesk made an offer to acquire Softdesk, effectively putting a stop to plans for selling Phoenix to Boomerang. As part of its approval of Autodesk's acquisition of Softdesk, the Federal Trade Commission encouraged the sale of Phoenix to Boomerang and the parties entered into a consent decree that provided that for ten years Autodesk would do nothing to hinder the development and marketing of this software or acquire any company that controlled it.

On February 21, 1997, Softdesk sold Phoenix to Boomerang which promptly was acquired by Visio for $6.7 million. Many of the programmers working on Phoenix, had already gone to work for Visio. At this point in time, Visio had annual revenues of $80 million and profits of $20 million. The expectation was that Phoenix would end up being somewhere between Visio Technical and AutoCAD.

The plan was to release Phoenix by the end of 1997 including DWG interoperability with the then current release of AutoCAD and capable of executing AutoLISP routines. The Phoenix nomenclature was dropped before the end of 1997 and the product was renamed IntelliCAD. It used DWG as its native file format and the command structure was similar to AutoCAD. The major exception was that IntelliCAD did not support Autodesk's ObjectARX . Other than ARX objects, Visio claimed that the software was compatible with AutoCAD from Release 10 through Release 14. The list price was initially expected to be set at $695 with the thought that dealers would sell it for under $500. Several thousand beta test copies were shipped in November 1997. For the quarter ending December 31, 1997, Visio generated revenues of $37 million, up nearly 95 percent over the prior year.

In early 1998, Visio was the driving force behind the establishment of the OpenDWG Alliance (subsequently known as the Open Design Alliance or simply ODA), an industry group focused on reverse engineering Autodesk's DWG format and making software for reading and writing DWG files available to members of the alliance. One of the first steps the alliance took was to run a full page ad in the *Wall Street Journal* attacking Autodesk for not making DWG information readily available to other software vendors. Visio had early acquired MarComp, the leading vendor of software tools for reading and writing DWG files and the company subsequently made the MarComp technology available to the alliance.

IntelliCAD 98 was finally released at the National Design Engineering Show in March 1998 in Chicago. As John Forbes, Visio's vice president of technical products stated "When you launch a new product such as IntelliCAD, you only get one chance to do it right."[36] At launch, the typical street price was only $349. This was a tremendous amount of technology for a very low price. IntelliCAD had some features, such as the ability to edit multiple drawings simultaneously, that the then current version of AutoCAD, Release 14, did not have.

[36] *Engineering Automation Report*, April 1998, Pg. 3

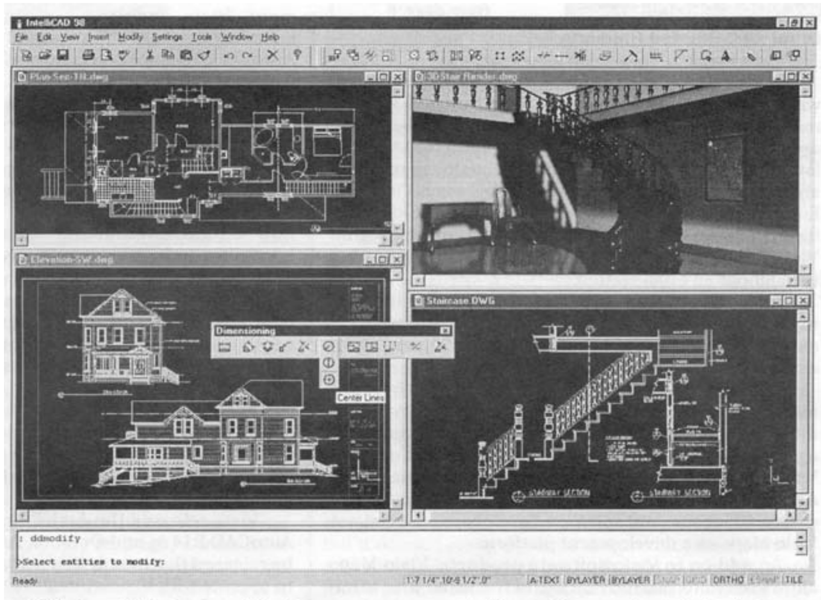

Figure 21.8
IntelliCAD 98 Multiple Drawing Interface[37]

A few months later, Visio began offering Visio Technical Design Suite which consisted of Visio Technical and IntelliCAD 98 for a street price of less than $500. Marketing CAD software did not seem to be a Visio strength and around late-1999, IntelliCAD was turned over to a group of software vendors organized as the IntelliCAD Technology Consortium. The consortium was given a perpetual license to the software and was allowed to sub-license it to anyone who joined the organization. The company's revenues in fiscal 1999 were $166 million, but it was apparent that Visio was starting to have growth pains.

In September 1999 Microsoft announced that it was acquiring Visio for $1.3 billion or $42 a share, a moderate premium over Visio's current stock price of $30. Visio became an operating division in Microsoft's Business Productivity Group, the same organization responsible for the company's Office software. Both Jaech and Johnson became Microsoft vice presidents.

IntelliCAD, meanwhile continues to be supported by the consortium and is available in seven languages in 30 countries. The organization is managed by a board of directors made up of individuals from the companies that license the software, some of which are interesting stories in themselves if only space permitted. There are over 30 members of the consortium and it is headed by Arnold van der Weide, president who also became chairman of the ODA board in late 2006. Much of the IntelliCAD software development is now done in Russia.

[37] *A-E-C Automation Newsletter*, January 1999, Pg. 9

 

# Chapter 22

# Analysis Companies

The first computers used for structural analysis were analog machines that solved series of differential equations. These early machines were built starting in the late 1930s and were mechanical in nature using springs, gears and other devices. One of the more significant such devices was the machine built by John Wilbur, a professor of civil engineering at MIT, which is shown in Figure 22.1. During the late 1940s and throughout the 1950s electronic analog computers were increasingly used to solve mechanical analysis problems, particularly in the aerospace industry. Most of these computers had difficulty solving problems with more than 200 degrees of freedom.

Figure 22.1
Professor John Wilbur and his mechanical computer

Even with this limitation, significant stress and vibration problems were successfully handled. According to Richard MacNeal, the founder of MacNeal Schwendler Corporation (known today as MSC.Software), Sud Aircraft in Paris built an analog computer that was capable of handling the analysis of the wing structure for the Concorde supersonic airplane, a problem involving 2,000 degrees of freedom. This was probably the upper limit for analog computers. Something better was obviously needed.

That something turned out to be a technique we know today as Finite Element Analysis or FEA. This approach involves dividing an object such as a mechanical part or a building structure into small elements and then using the mathematical relationships between these element to compute stresses and deflections caused by various loading conditions. FEA technology evolved as an academic concept in the 1950s and soon caught the attention of structural analysts in the aerospace industry and at NASA. For the most part this chapter focuses on companies that specialized in the development and marketing of software associated with finite element analysis (FEA).

The software used to create sets of elements is usually referred to as finite element modeling (FEM). The term frequently used to describe this data was a finite element mesh and the software was also called a mesh generator. Another way of describing the complexity of an analysis problem is by stating the number of degrees of freedom the structure has. This is usually some multiple of the number of elements. Models are also referred to in terns of the number of nodes – the vertexes where two or more elements meet.

One of the first papers on this subject was published in 1956 in the Journal of Aeronautical Engineering by a group of Boeing engineers led by Jonathan Turner.[1] Another early pioneer in this area was Raymond Clough, a professor of mechanical engineering at the University of California at Berkeley who published a paper, “The Finite Element Method in Plane Stress Analysis” at an ASCE conference in 1960.[2] As described below, several others were experimenting with this new analysis technique at the same time.

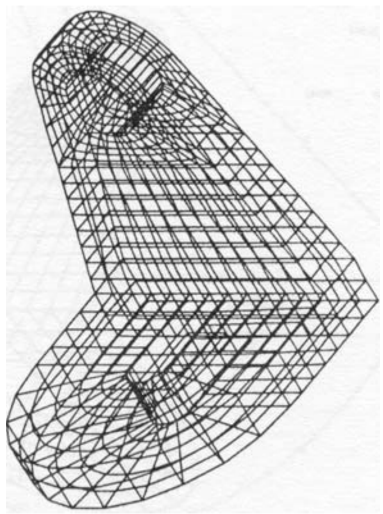

Figure 22.2
Typical Finite Element Model[3]

The nature of FEA has changed significantly over the years. Early software was implemented on batch-oriented mainframe computers. The process most commonly used for building FEA models prior to the introduction of computer graphics involved taking drawings of the object to be analyzed, laying out a grid on these drawings and then manually dividing the object into discrete elements. Since the accuracy of the results often depended upon the number of elements in the model, analysts tried to split up the part as finely as possible given limitations of time and budget. They had to keep in mind that the time to compute a solution went up geometrically with the number of elements in the model. The entire process for an initial analysis of a part with 1,000 elements would have taken several weeks. Subsequent analyses typically took several days.

Each element was entered on a coding sheet, the sheets were given to a key punch operator and entered into punch cards and the data on these cards was printed so the engineers could check for obvious errors. Small numerical errors were difficult to find as were missing elements or missing information defining how each element was connected

[1] Truner, M. J. et al – *Stiffness and Deflection Analysis of Complex Structures* – Journal of Aeronautical Engineering, Pg. 805-823, 1956
[2] Carrabine, Laura – *Early Masters of the Mesh* – Mechanical Engineering Design - The American Society of Mechanical Engineers, November 1999
[3] Marino, Carlos – *An Integrated Approach to Computer-Aided Design and Analysis* – First Chautauqua on Finite Element Modeling, Schaeffer Analysis, Inc., Pg. 284, 1980

 

to adjacent elements. These points of connection are referred to as nodes. Only after the data was thoroughly checked by hand could it be run through a FEA program and the results printed out. Some, but not many, organizations used plotters to create drawings of the FEA input data or to illustrate results. More often, results were reviewed by going through page after page of numerical listings and plotting this information by hand.

The process was excruciatingly tedious, susceptible to error and costly. Even moderate size problems required a large amount of time on fairly large computers. Slight errors in preparing the data often made these expensive computer runs worthless. If FEA were to fulfill its promise, the process needed improvements from end to end. A number of companies started to envision the use of interactive graphics as a means of improving this process.

By the mid 1970s, computer graphic systems were starting to be used to prepare FEA data and to view results. For example, McDonnell-Douglas Automation offered a timesharing program called FASTDRAW that could be used to create element data and then transfer the information to a mainframe analysis program. SDRC was another company offering this type of software as described in Chapter 17. At the time, most analysis work was done by highly educated engineers and mathematicians, often with Ph.Ds.

A decade later most CAD vendors offered programs that would take a three-dimensional model and generate FEA input data with minimal user intervention. With greater automation of the mesh generation process, models became larger and larger. It was not unusual for a large model to consist of 100,000 elements and there were a growing number of element types being used. Some of these were fairly complex in order to solve problems such as those involving thin shell structures. With the computers of the early 1990s, a large problem could still take several days to solve, even on a supercomputer. One result was an increased focus on developing new mathematical procedures that would enable analysts to economically solve larger and larger problems.

Today, large models can consist of several million elements yet are solved in relatively short order on desktop computers. One major change is that FEA software is typically used interactively by design engineers now as well as by analysis professionals. If an engineer is trying to reduce the weight of a part, software is readily available that will optimize the shape of the part. In some industries, FEA simulation has eliminated most, if not all, physical prototype stages. Today, crash analysis in the automobile industry is primarily done using FEA rather than building physical prototypes and smashing them into a wall.

The March 1992 issue of *Computer Aided Design Report* listed 28 different companies that offered finite element analysis software.[4] Some of these, including Computervision and Intergraph, are discussed in separate chapters while others are discussed in this chapter. Space constraints do not permit covering every company, however.

**ABAQUS (Hibbitt, Karlsson & Sorensen)**

The early history of ABAQUS is very tightly connected with the early history of MARC Analysis Research Corporation described later in this chapter. Both companies evolved out of work done at Brown University in Providence, Rhode Island starting

[4] *Computer Aided Design Report*, March 1992, Pg.11

around 1965. David Hibbitt received his Ph.D. in 1972 from Brown after completing a thesis involving computational mechanics using the FEA method. Hibbitt was hired by MARC Analysis Research Corporation where the code developed as part of the thesis formed the basis for the initial MARC software. Paul Sorensen also worked briefly for MARC before returning to Brown to complete his Ph.D.

Throughout the 1970s and into the 1980s, MARC was provided to users on a time-sharing basis, particularly via Control Data Corporation’s Cybernet service. Dr. Bengt Karlsson worked for CDC in Sweden supporting a number of different analysis programs. In 1976 he moved to the United States and also joined MARC.

A year later, Hibbitt decided to form a new company to develop and market FEA software that could be used by a broad range of engineers. This software was called ABAQUS. Karlsson joined him in the effort as did Sorensen who was working at General Motors. The three incorporated Hibbitt, Karlsson & Sorensen or HKS as it was most commonly known, in February 1978.

Like MARC, ABAQUS was initially distributed via CDC’s Cybernet service. The company’s first customer was Westinghouse Hanford Company which used the software to analyze nuclear fuel rod assemblies. Over the years ABAQUS developed a following among engineers working on complex projects such as offshore oil and gas platforms as well as in the automotive industry for vehicle simulation. The company developed a reputation of working closely with ABAQUS users in deciding where to concentrate its development resources.

The basic software, eventually known as ABAQUS/Standard, was complemented by other software tools including ABAQUS/Explicit, a dynamic analysis package released in 1991, and ABAQUS/CAE, a package for building FEA models from CAD data released in 1999. The company’s name was changed to ABAQUS, Inc. in late 2002 to reflect the company’s focus on this product line. Then in October 2005, the company with its 525 employees was acquired by Dassault Systèmes for $413 million or about four times the company’s annual revenue of approximately $100 million.

David Hibbitt was still with the firm he started as chairman while Mark Goldstein was president and CEO when the company was acquired by Dassault.

**ANSYS (Swanson Analysis Systems)**

John Swanson joined Westinghouse Astronuclear Laboratory in Pittsburgh in 1963 as manager of structural analysis. While working for Westinghouse he completed his work on a Ph.D at the University of Pittsburgh in applied mechanics in 1966. He had earlier received his bachelors and masters degrees in mechanical engineering from Cornell University. While at Westinghouse, Swanson promoted the use of computer models to predict the stresses and displacements of nuclear reactors due to thermal and pressure loads.

Recognizing the future potential for this analysis technology, he recommended that Westinghouse begin the development of general purpose FEA software. When the company turned him down he decided to start his own company, Swanson Analysis System, in 1970. The first version of what soon became the company’s flagship product, ANSYS, was developed using a time-shared mainframe at U.S. Steel. The initial version of the software was finished by late 1970 and Swanson’s first customer was Westinghouse.

 

While ANSYS initially was implemented on mainframe and supercomputers, Swanson was an early supporter of the new generation of 32-bit minicomputers such as the Digital VAX 11/780 which was quickly becoming popular in engineering and academic circles. The company also recognized the need for both model preparation and results viewing software. Its popular Finite Element Modeling (FEM) package was called PREP7 while its viewing program was POST1. The use of all three provided a well integrated FEA solution.

Over the next decade, the company gradually built its market presence, becoming a well respected vendor of technical software although not a very large one. The company expanded into the area of computational fluid dynamics when it acquired Compuflo, Inc., the developer of FLOTRAN software, in 1992. In early 1994, TA Associates, a Boston, Massachusetts-based investment firm, acquired a majority interest in Swanson Analysis. One result of this deal was that John Swanson relinquished his position as president and CEO and for the next five years acted in the role of chief technologist. He was replaced by Peter Smith, an ex-Digital Equipment Corporation executive who soon changed the company's name to ANSYS, Inc. Swanson was still a major stockholder in the company and remained on the company's board of directors until early 2000.

By late 1994, the company was focused on several technical objectives. ANSYS Designer Series was being promoted as being design engineer friendly so that many problems could be addressed without the need to utilize analysis specialists. ANSYS 5.1 was also being used increasingly for design optimization. The software supported over 100 different element types and was capable of solving static and dynamic problems, including linear and nonlinear cases. Adaptive meshing automatically adjusted the size of the finite element mesh until the solution converged. Previously, this was a time consuming task for the engineer.

ANSYS 5.1 also including new solution technology that processed FEA models as much as an order of magnitude faster than earlier version although two to four times faster was more typical. Performance was becoming increasingly important as models with over 100,000 elements were increasingly common. This was an area where John Swanson spent a considerable portion of his time once he was no longer president. Significant performance enhancements were periodically incorporated into subsequent software releases. In particular, ANSYS was a leader in applying multiprocessing techniques to FEA computation. Today, ANSYS is regularly used to solve models with well over a million elements.

ANSYS was also working closely with CAD software vendors including PTC and Autodesk to integrate its software with a variety of CAD packages. Its ANSYS/AutoFEA package, introduced in October, 1994, was tightly integrated with AutoCAD Release 12 and sold for just $1,200. A more advanced version, ANSYS/AutoFEA 3D was released in June 1996 at a suggested price of $3,800.

The company was recognized as a leader in the area of multiphysics problem solving. This refers to situations where an analyst addresses problems involving the combination of structural, thermal, electromagnetic and vibration forces. In June 1996, the company had an initial public offering, selling 3,580,000 shares of stock for $13 per share and raising over $46 million for the company. Shortly thereafter, the company's

 

300 employees moved into a new facility in Canonsburg, Pennsylvania, 15 miles southwest of Pittsburgh.

During the period from 1995 through 1999 the company's business model changed significantly. While overall revenues rose from $39.6 million to $63.2 million, software lease revenues dropped from $18.1 million to $16.6 million. Meanwhile service revenue more than tripled from $7.0 million to $22.2 million and the sale of fully paid up licenses nearly doubled from $14.5 million to $24.4 million.

Jim Cashman, became president ANSYS in April1999 and CEO in February 2000. He had joined the company as vice president of operations in 1997 after working for PAR Technology Corporation, Metaphase, and SDRC. He replaced Smith who remained as the company's chairman. In February 2003, ANSYS acquired CFX, a computational fluid dynamics software company for $21.7 million.

In February 2001, Brad Morley, the former CEO of Applicon, joined the ANSYS board of directors. The company has done well in recent years with revenue in 2005 exceeding $155 million. In May 2006, ANSYS completed the acquisition of Fluent, a vendor of Computational Fluid Dynamics (CFD) software for $565 million in stock and cash. The result was a company with approximately 1,350 employees with consolidated revenues of nearly $264 million in 2006.

**Computer Aided Design Software, Inc (CADSI)**

Computer Aided Design Software, Inc (CADSI) began as a result of work done by Edward Haug, a professor of mechanical engineering at the University of Iowa. Around 1980, engineers at the U.S. Army Tank and Automotive Command (TACOM) in Detroit, Michigan were interested in improving the mathematical algorithms and formulations used to solve equations of motion for constrained multibody mechanical systems. This led to TACOM funded research at the University of Iowa for computer simulation of vehicle dynamics. Professor Haug and his associates delivered this software to the army around 1982.

Initial tests of the software proved the numerical accuracy of the Dynamic Analysis and Design System (DADS) algorithms and the software quickly evolved to handle a wide variety of truck and tank simulations. Prior to DADS, all software packages tested by TACOM failed to provide the necessary numerical stability, accuracy, and reliability. In 1983 Haug decided to form a company based on this dynamics technology and started CADSI in Oakdale, Iowa to develop software products and provide consulting services in this area. The company's primary competitor was Mechanical Dynamics which is discussed below.

By 1985 Haug decided he had more interest in being a professor than a businessman so he recruited Rex Smith, a vice president of R&D at Applicon to become CADSI's president and CEO. Smith had earlier held a similar position at SDRC. The first commercial version of DADS was released to customers in 1986. DADS was one of the first motion analysis packages to incorporate a graphics pre- and post-processor. This software ran on a wide range of computer platforms including PCs and UNIX workstations. In 1989 the software was priced at $27,000. Working with Boeing, CADSI also developed a version of DADS that was integrated with Dassault Systèmes CATIA called CATDADS. Other interfaces were soon developed for SDRC's I-DEAS and PTC's Pro/ENGINEER.

In mid-1994 IBM licensed CADSI to sell PolyFEM, a linear structural analysis packaged developed by IBM's Almaden Research Laboratory in San Jose, California. This software was initially written to work with CATIA. In 1996 IBM had discussions with several companies about selling the PolyFEM technology outright. CADSI was the successful bidder although it had to raise outside funding to finance the purchase. CADSI had hoped to sell PolyFEM to Pro/ENGINEER users who were already using DADS but PTC's acquisition of Rasna (see Chapter 16) made this rather difficult.

CADSI did put together a combination of DADS and PolyFEM with an interface to SolidWorks called DesignWorks. CADSI was the only company at the time that offered a software product that combined motion analysis with structural analysis.[5]

In early 1999, CADSI was acquired by LMS International, based Leuven, Belgium. Various versions of DADS are still marketed including DADS/Engine, developed in cooperation with BMW. PolyFEM is no longer marketed, however.

**Computers and Structures, Inc.**

One of the early pioneers in the FEA area was Dr. Edward L. Wilson at the University of California at Berkeley. He was the original developer of the Structural Analysis Program (SAP) which was first released in 1970.

Computers and Structures (CSI) was founded in 1975 by Ashraf Habibullah to market and support SAP which is still widely used today, particularly for the analysis and design of civil structures. CSI products are licensed to thousands of structural engineering firms throughout the United States and in more than 100 other countries. The current package, SAP2000, is intended for use on structures such as bridges, dams, stadiums, industrial structures and buildings. Other software has been developed specifically for multi-story building structures, such as office buildings, apartments and hospitals.

**MARC Analysis Research Corporation**

Although it never became a major player in the mechanical CAE world, MARC Analysis Research Corporation was one of the industry's pioneering firms. The company got its start in 1965 when a group of researchers at Brown University in Providence, Rhode Island began development of finite element software which eventually became a commercial package also called MARC.

The company was founded in 1971 and the first version of the MARC software was introduced in 1972. Over the years, MARC became one of the leading vendors of non-linear analysis software. A brief word about what is meant by non-linear analysis may be in order. Much of the world we live in is not necessarily linear in nature. Materials such as rubber respond far differently to loads and constraints than do most metal objects. Examples are car door seals, shock mounts and gaskets.

Metal products also react differently while being formed than they do in operation. A good example is a part fabricated by hot forging. The hot metal is in an elastic state while it is being shaped by rigid dies. As the material cools, the part's shape changes. The process is further complicated by the fact that even fairly massive dies will deform during the forming process. MARC's non-linear FEA software was used to make this process more predictable and to reduce many of the physical prototypes previously required.

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[5] *Engineering Automation Report*, November 1998, Pg. 6

 

One of MARC's early employees was David Hibbitt who completed his Ph.D. thesis at Brown University in 1972. The thesis involved computational mechanics based on the finite element method. The software he developed at Brown formed the basis for the initial version of MARC. MARC was made available to users on a time-sharing basis, particularly via Control Data Corporation Cybernet service. CDC provided access to MARC throughout the 1970s and into the 1980s. Hibbitt remained with MARC until 1977 at which time he left to begin the development of the ABAQUS FEA software as discussed earlier.

The MARC software was a general-purpose FEA program intended for advanced engineering analysis. It supported over 130 different element types, facilitating the modeling of everything from thin shells to cables. MARC incorporated an adaptive meshing methodology that increased the number of elements being used until a pre-established error criteria was satisfied. The company paid particular attention to modeling gaps between parts and taking into consideration how stresses and temperatures propagated between parts that were constantly or intermittently in contact with each other. The software specifically handled situations where a deformable object (perhaps a rubber mounting) contacted a rigid surface.

Although MARC could accept Finite Element Meshes generated by third party software packages, the company offered its own modeling program, Mentat II. This package enabled a user to either import geometry from CAD systems or the geometry could be created directly in Mentat II. In 1996 the latter approach was improved by incorporating Spatial Technology's ACIS geometric kernel into Mentat II.

In the mid-1990s MARC sought to broaden its customer base by offering application specific solutions. One of these was MARC/AutoForge. This program applied FEA to both hot and cold metal forming such as what was found when using forging, extruding, rolling and multistage manufacturing processes. The basic technical problem in applying FEA to these procedures was that as the metal was deformed, the finite elements used to model the part were also deformed. Very quickly, the model ceased to provide accurate results. MARC/AutoForge addressed this problem by continually remeshing the model as it analyzed each step of the forming process.

Between the late 1970s and 1992, MARC was a well respected but rather minor player in the FEA market. In 1992, the company hired Lou Crain as president and CEO. Crain had been with PDA Engineering from 1975 to 1989 including serving as head of that company's PATRAN division. By 1996 Crain had built up MARC's revenue to about $20 million annually, a level it sustained for the next several years.

The financial backers of the company decide that MARC was not going to become a major player in this market and Crain left in late 1998. In May 1999 the company was acquired by MacNeal-Schwendler Corporation (now MSC.Software as described below) for $36 million.

**Mechanical Dynamics Incorporated (MDI)**

Mechanical Dynamics Incorporated was started as a consulting firm in Ann Arbor, Michigan by a group of University of Michigan engineers in 1977. Among the founders were Michael Korybalski and John Angell who both stayed with MDI for several decades, Korybalski as president and CEO and Angell as chief technologist. The third founder was Milton Chace who was a professor of mechanical engineering at the university. The three had developed a two-dimensional mechanisms analysis package called Dynamic Response of Articulated Machinery (DRAM) prior to starting MDI. The company's early offices were above an ice cream shop near the U of M campus.

MDI's early work soon led it to concentrate on analyzing mechanical mechanisms. Engineers are faced with two major problems when designing objects that have complex moving parts – will the mechanism move in the manner expected and what loads are exerted on the these parts as the object moves through its range of motion. As an example, consider a large front-end loader user in mining operations. If the unit is standing still, the designer can estimate the forces on each part of the mechanism when the bucket is in a particular orientation. But what if the loader is moving while raising the bucket and one wheel drops into a large hole?

The firm's product suite was called Automatic Dynamic Analysis of Mechanical Systems (ADAMS). There were a number of different modules used for building models, solving mechanism equations, verifying the basic motion of a proposed design, simulating complex operations and viewing the results. A major portion of the company's business came from manufacturers of automobiles and trucks. MDI developed ADAMS modules specifically for this industry including ADAMS/Vehicle which was used to help design suspension systems as well as study the handling qualities of proposed vehicles.

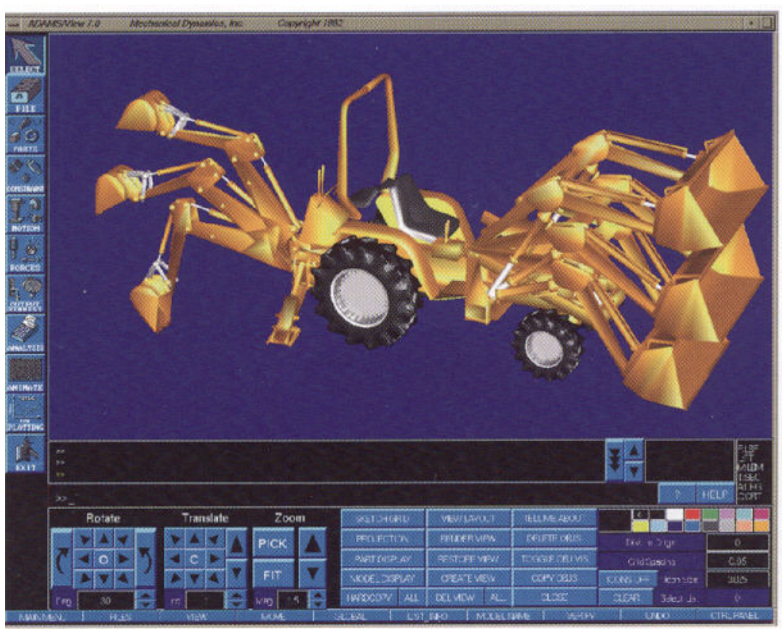


Figure 22.3
MDI's ADAMS being used to analyze a front-end loader and backhoe

ADAMS ran on a variety of 32-bit computers, including those sold by Digital and Prime as well as UNIX workstations and PCs. In the mid-1990s the ADAMS Full Simulation Package which included both ADAMS/View and ADAMS/Solver sold for $24,000 on UNIX platforms and $10,000 on PCs.

 

MDI went public in mid-1996 at which time the company had annual revenues of about $25 million which increased to $57 by 2001. In March 2002, MDI was acquired by MSC.Software in a cash deal worth approximately $120 million.

**Moldflow**

Most plastic parts are produced using a process called injection molding. Once a part is designed, a mold is machined that corresponds to the shape of the part. This mold is placed in a molding machine and hot plastic is injected into the mold. After the plastic cools it can be removed and the process repeated. The objective is to rapidly produce parts that when cooled, do not shrink or warp and faithfully represent the initial design. Prior to the introduction of mold analysis software, this was a trail and error process that often required several sets of molds and cooling lines in order to produce acceptable parts.

Moldflow Pty. Ltd. was founded in Australia in 1978 by Colin Austin and shortly thereafter introduced its first software package for analyzing plastic injection molding processes using a form of finite element analysis. The intent of this software was to determine if plastic at a specified temperature would flow into all parts of the mold and if that plastic would uniformly cool.

Throughout the 1980s and early 1990s, the company's business model was primarily to negotiate joint marketing agreements with mainstream CAD software vendors. Nearly every such company offered interfaces to the Moldflow software and many resold the package. In the mid-1980s the company opened several design centers around the world which were not particularly successful from a financial point of view. In 1987 Austin hired Hugh Henderson to take over day-to-day management of the company. One of his first steps was to close the design centers. Some of the individuals running these centers set up their own independent mold design businesses.

By mid-1989, Moldflow's software was available on 18 different platforms ranging from PCs to Cray supercomputers. The company's products included:

- Moldflow for mold filling analysis
- Moldtemp for mold cooling analysis
- MetlFlow for predicting the filling of die castings.

The software was priced based upon the class of processor it was being run on. At the time, these costs ranged from $6,000 to $30,000 per year for each package. The company was also working on a package to do shrinkage and warpage analysis.[6]

In June1996, Marc Delude, who had been a marketing vice president at PTC, became president and CEO of Moldflow and the company's headquarters were relocated from Australia to the United States. Current corporate headquarters are in Framingham, Massachusetts.

By 1997, there were over 4,500 users of Moldflow Dynamic Series software in over 50 countries.[7] At this point, the company had about 100 employees and revenues of $16 million annually. In addition to the Dynamic Series' comprehensive set of analysis capabilities (this software started at $39,000 for a workable suite of modules), the company introduced a lower cost package called Part Advisor in 1997. It was priced at $9,000 for single license.

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[6] *Computer Aided Design Report*, April 1989, Pg.8
[7] *Engineering Automation Report*, June 1997 Pg. 6

 

Part Advisor software was tightly integrated with a number of different CAD packages including Pro/ENGINEER and SolidWorks. It used a simplified approach to define part data for analysis and included a materials library that made selecting plastic materials quite easy. Analysis results such as the time for filling the mold were represented in color coded visual images.

One particularly relevant output was a "Confidence of Fill" diagram that showed those areas of the part where there was a high, medium or low confidence that the part would fill correctly. Based on this output a designer might change the shape of the part, modify the locations where the material was injected, change the temperature of the material or even change the type of material. The software significantly improved the productivity of the injection molding process as well as reduced the time it took to initially produce acceptable parts. Numerous other mold analysis packages have been introduced by the company in subsequent years.

Moldflow went public in 2000 and subsequently acquired C-MOLD, another significant vendor of injection molding analysis software. As this is being written in mid-2007, the company's stock price is about $23.00 per share. This is far better than the low of $4.00 in October 2002 but still below the $30 it hit in early 2001. The company's revenues are about $70 million annually – more than four times what they were a decade earlier. It currently has slightly over 300 employees.

Roland Thomas, who had joined the company in 1982 in Australia and served as vice president of R&D from 1997 to 2002 became president and CEO in June 2002, replacing Delude.

**MSC.Software (McNeal-Schwendler Corporation, PDA Engineering, Mechanical Dynamics, Knowledge Revolution, MARC Analysis Research Corporation)**

Today's MSC.Software is an assemblage of a number of companies that for many years were competitors. Most of these are described separately in this chapter while this section focuses primarily on MSC itself. Much of the early history of MSC is derived from a fascinating book written in 1988 by one of the company's founders, Dr. Richard MacNeal. Called *The MacNeal Schwendler Company – The First Twenty Years*, it was a limited edition book published by the company that talks frankly about the struggles of getting FEA accepted as an engineering technology.[8]

MSC was founded in 1963 by MacNeal and Robert Schwendler. Prior to starting MSC, MacNeal received a Ph.D in electrical engineering from California Institute of Technology in 1949 and joined the school's faculty working in its Analysis Laboratory. At the time, engineering analysis was mostly done on analog computers. A number of the laboratory's staff members including MacNeal formed Computer Engineering Associates (CEA) in 1952 to commercialize the laboratory's work building analog computers. MacNeal continued on the CalTech faculty until 1955 at which time he went to work for Lockheed. He returned to CEA a year later, eventually becoming manager of engineering analysis.

MacNeal met Bob Schwendler in 1960 when he visited General Dynamics' Convair plant in Fort Worth, Texas. Schwendler was the engineer in charge of an analog computer used to simulate aircraft designs. MacNeal offered Schwendler a job at CAE which he accepted.

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[8] MacNeal, Richard H., *The MacNeal Schwendler Company – The First Twenty Years*, 1988

 

Figure 22.4
Dick MacNeal at Console of Analog Computer in 1960

MSC was formed by MacNeal and Schwendler in early 1963 with Arlyn Winemiller, who had joined CAE from Martin in Denver as the third founder. The company was started with $18,000 provided by the three founders. The only other employee was Grace Hunter who had been MacNeal's secretary at CAE. MSC's initial business was intended to be engineering consulting and analysis although they were not sure if the latter would be done on analog or digital computers. The company's first project was the analysis of an arch dam for which they wrote their first FORTRAN computer program which was named SADSAM (Structural Analysis by Digital Simulation of Analog Methods). During the company's first year it had revenues of about $90,000 and made a profit of $866. SADSAM was used by MSC until 1976 and its use was continued by Hughes Helicopter at least until 1988.

The most significant project in the history of MSC was, of course, its work on the development of NASTRAN (NASA Structural Analysis). By 1964 several aerospace firms had developed proprietary FEA software but there was no generally available software that engineers at other companies or universities could use. About this time NASA began putting together the specifications for a generalized FEA program and a Request For Proposal was distributed in July 1965. MSC decided to team with Computer Sciences Corporation in bidding for this work after being unable to reach agreement with IBM or Lockheed. Martin Aircraft, located in Baltimore, Maryland, subsequently became the third member of the team. In December 1965 the MSC team of which CSC was the prime contractor, was awarded one of two contracts to prepare a Technical Evaluation Report. The other contract was awarded to a team led by Douglas Aircraft. MSC's report was submitted in the spring of 1966 along with a proposal to implement the software at a cost of somewhat over $1 million.

The MSC team was awarded a contract for the development of NASTRAN[9] in July 1966. MSC was responsible for defining the analytical aspects of the software while CSC personnel did the actual programming. Much of the mathematical work was done by Professor Caleb W. (Mac) McCormick of Caltech who took a leave of absence to work on the project and subsequently joined MSC as a full time employee. Development of

[9] The name NASTRAN was adopted by NASA in 1967.

NASTRAN was delayed by the need to resolve a number of technical issues fundamental to FEA processes and the lack of available NASA computers. Most of the programming work was done on IBM 7094s and CDC 6600s although towards the end, IBM 360 computers played a major role. The software was delivered to the Goddard Space Flight Center in 1969. Although small by today's standards, the program was able to handle problems with over 10,000 degrees of freedom.

Between 1965 and 1970 MSC received a total of $635,000 from CSC for its work on the development of NASTRAN. This version of the software eventually became known as COSMIC NASTRAN. COSMIC was a federally funded program run by the University of Georgia which was used to distribute government developed software for a small reproduction fee. Initially, the fee for COSMIC NASTRAN was $1,750. NASTRAN was a large program consisting of over 150,000 FORTRAN statements. During this period, MSC continued to develop and market analog computer components although by 1972 this activity was generating very little revenue.

Beginning around 1969, MSC began developing a consulting practice involved in assisting companies interesting in installing and utilizing NASTRAN including Vought, Aerojet and Bell Helicopter as well as a number of government laboratories. MSC was also awarded several NASTRAN maintenance contracts by NASA starting in June 1971 with Control Data Corporation acting as a programming subcontractor. This arrangement continued until early 1974 when NASA and MSC parted ways over the NASA's perception that MSC was taking unfair advantage of this contract in regard to its other consulting business.

The MSC and NASA versions of NASTRAN began diverging as early as 1971 leading to the company's proprietary implementation being called MSC/NASTRAN. The company began to offer MSC/NASTRAN to other companies for a support fee of $500 per month. The first customer under this arrangement was McDonnell Douglas in Saint Louis, Missouri. The company also began providing its software to service bureaus on a royalty basis. CDC Cybernet soon was producing 60 percent of MSC's lease and royalty revenue. For the next several decades, charging a monthly or annual fee for its software rather than selling fully paid licenses became a basic business characteristic of MSC.

The company opened a European office in Munich, Germany run by Leonard Peterson and an office in Japan run by H. Watanabe. Mac McCormick was instrumental in both of these international efforts, even going to the point of learning Japanese in order to better work with Japanese customers.

MSC continued to rapidly expand its version of NASTRAN with new element types and new analytical processes. By early 1976, less than 30 percent of MSC/NASTRAN contained the same code as COSMIC NASTRAN. New capabilities included a preprocessor developed in Germany by Peterson called MSGMESH. By this point MSC/NASTRAN was being used to solve problems with as many as 30,000 degrees of freedom. By 1978 MSC had 85 contracts for the use of MSC/NASTRAN and royalty revenue that year was nearly $1.4 million, the majority of which came from contracts with data centers such as CDC. MSC was now charging its industrial customers $1,000 per month for MSC/NASTRAN while NASA has raised its fee for COSMIC NASTRAN to $4,000 per year.

For the most part, MSC was conservatively managed during the 1970s. From 1970 to 1976, the company had about 20 employees. It started to grow rapidly from that point forward as revenues, mostly from MSC/NASTRAN, increased 40 percent annually.

Dr. Joseph Gloudeman joined the company in 1978 from Rockwell. MacNeal was enthusiastic about recruiting him since Glouderman brought a degree of management experience that the company's then current executives lacked. He was also seen as a possible successor to MacNeal who was 55 at the time. Initially hired to head marketing and advanced product development, Glouderman became president and COO shortly before the company went public in May 1983.

In 1979, the company opened an a regional office in New England with Dr. Harry Schafer in charge. Actually, a new company was established called Shaffer Analysis, Inc with MSC owning 80 percent. Shaffer had been a professor at the University of Maryland and his principal role was to continue training people to use FEA with emphasis on MSC/NASTRAN. Shaffer also ran a series of conferences in the early 1980s on FEA technology called the Chautauqua on Finite Element Modeling. Schaffer's relationship with MSC lasted for several years at which time he purchased MSC's interest in his company for basically what MSC had originally invested.

Until 1978, MSC/NASTRAN was supported on mainframe computers from CDC, Univac and IBM. These were expensive machines and MSC was unable to afford a machine of its own. This situation changed with the introduction of 32-bit computers such as the Digital VAX 11/780. In mid-1978 MSC negotiated an agreement with Digital to port its software to this new machine and installed an 11/780 that fall. Within a few months, the company had MSC/NASTRAN up and running and by January 1983, there were 64 customers using this machine.

A major change took place when Bob Schwendler passed away unexpectedly on January 2, 1979. Mac McCormick was made executive vice president in his place and Joe Glouderman became vice president of marketing.

In addition to the VAX 11/780. MSC began supporting a wide range of other computers ranging from the Apollo engineering workstation to the Cray supercomputer. Software development during the early 1980s focused on adding nonlinear capabilities as well as work on pre- and postprocessors. A new package in this latter area, MSC/GRASP, was released in 1982. Many MSC customers, however, used PATRAN software from PDA Engineering for this function.

For over a decade, the relationship between NASA and MSC had been basically problem free. This came to an abrupt halt with a letter dated August 26, 1980 in which NASA claimed that MSC had inappropriately been using software code developed as part of NASTRAN maintenance work MSC performed for NASA in the early to mid-1970s. This letter was a result of an audit NASA had initiated more than a year earlier. According to MacNeal, the audit was most likely the result of a complaint lodged by Tony Cappelli, the president of Universal Analytics. This company resold a version of COSMIC NASTRAN it called UAI/NASTRAN.

The dispute with NASA dragged on for over two years until it was settled with MSC paying NASA $125,000 for all rights to use the software it had previously developed under its contracts with NASA. This was far less than the several million dollars the government originally wanted. Resolution of the problem was critical in that MSC was preparing to go public. The public offering took place on May 5, 1983 at an initial price of $29 per share. The stock closed that day at $36.75. In the process, the company raised approximately $10 million while stockholders sold over $25 million of stock. MSC's stock was listed on the American Stock Exchange. Joe Glouderman became CEO in March 1985, at which point Dick MacNeal retired. This lasted until 1991 when the company's earnings came up short. Glouderman was pushed out as CEO and MacNeal rejoined the company as president and CEO.

The company continued to grow at a fairly consistent pace with annual revenues reaching $65 million and earnings of $12 million for the year ending January 31, 1993. Software development included the introduction electromagnetic analysis (MSC/EMAS) and dynamic analysis (MSC/DYTRAN) as well as the support of a growing number of computer systems including Hewlett-Packard and Sun Microsystems workstations. The company continued to license its software on an annual basis as well as beginning to sell fully paid-up licenses with the cost determined by the power of the computer being used and the maximum size models that could be analyzed.

A new pre- and postprocessor, MSC/XL was introduced as well as a version that incorporated software from Aries Technology (see Chapter 21). The latter was called MSC/XLplus. The relationship with Aries eventually led to MSC acquiring the company for $20 million in September, 1993. With this acquisition, Larry McArthur became president and COO while Dick Miller became MSC's vice president of corporate marketing and general manager of the Aries Division. The other key member of the management team was Dr. Dennis Nagy who was senior vice president, operations. One byproduct of the Aries acquisition was that the people at MSC's headquarters who were working on MSC/XL were reassigned to the Aries division. On the flip side, Aries sales organization was absorbed into MSC's sales operation.

The Aries acquisition was followed less than a year later by the acquisition of PDA Engineering (see below) for $56 million. At the time, MSC was an $80 million company while PDA was doing $42 million annually. The acquisition was driven by two observations. First, MSC's management felt that the mechanical design market was on the verge of significant consolidation – a position that proved to be particularly perceptive although it might have taken longer than they expected. The other observation was that the two companies were spending disproportionate resources developing software to compete with each other. The plan was that Aries would provide software targeted at the design engineer while PDA would target the professional analyst. Lou Delmonico, PDA's CEO at the time of the acquisition left soon after the deal was completed but Tom Curry, PDA's president and COO stayed with the merged company.

The acquired products were renamed MSC/ARIES and MSC/PATRAN, respectively. McArthur left MSC in late September 1994 and Miller left several months later. The company announced that it had initiated a search for a new president and CEO. In November 1994, MSC demonstrated a Windows version of MSC/NASTRAN price at $5,000 per copy. On the financial side, the company was struggling to increase revenues of the combined PDA and MSC business. It took until 1996 before it was heading in the right direction.

Like most other FEA software firms, MSC worked hard to increase the performance of its analysis software. MSC/NASTRAN Version 68.1 released in mid-1995 was significantly faster than prior releases, enabling users to tackle larger models in a reasonable amount of time. The company also began to work more closely with CAD software firms, probably influenced by personnel who joined the company as a result of the Aries and PDA acquisitions. One example was that in late 1995, MSC signed a joint development and marketing agreement with EDS Unigraphics and an agreement with Matra Datavision under which the latter company distributed QUICKSOLVER, a subset of MSC/NASTRAN.

MSC promoted Curry to president and CEO in March 1996. A few months later, the company decided to focus on structural analysis issues and sold its electromagnetic analysis business to Ansoft for $5.6 million. MSC began to concentrate on specific market segments. The company set up an aerospace unit under Kenneth Blakeley and an automotive unit under Thomas Tecco.

One significant development in August 1997 was the release of a Windows version of MSC/PATRAN. This was followed in November by the launch of MSC/InCheck which provided stress, vibration, and buckling simulation inside SolidWorks 97Plus. A few months later a new version added shape optimization and steady-state heat transfer simulation to the package. In December 1998, Curry was replaced as president and CEO by Frank Perna, Jr. who also became chairman, replacing George Riordan who had been serving as chairman. Perna had previously been CEO of EOS Corporation, a high technology electronics manufacturer. About the same time, MSC announced plans acquire Knowledge Revolution, the vendor of the Working Model suite of motion simulation software for $19 million in cash.

In March 1999 the company announced plans to change its name to MSC.Software to reflect its growing interest in providing software and services via the Internet. In May 1999 the company acquired MARC Research and Analysis Corporation for $36 million. This was followed in July with the acquisition of Universal Analytics, the vendor of UAI/NASTRAN and in November by the acquisition of Computerized Structural Analysis and Research Corporation (CSAR) the vendor of CSA/NASTRAN.

At this point, MSC controlled over 95 percent of the NASTRAN software market which caught the attention of the Federal Trade commission. After several years of hearings and negotiations, MSC agreed to a consent decree that provided in part:

> "The principal relief under the proposed Order is to require the Respondent to divest, within 150 days after entry of the Order and to up to two acquirers to be approved by the Commission, perpetual, worldwide, royalty-free, and non-exclusive licenses to the key intellectual property needed by a new competitor to compete in the sale and licensing of advanced Nastran software."[10]

Soon after the consent decree was finalized, MSC negotiated a license agreement with EDS PLM Solutions (The name of UGS at the time) for that company to develop and market its own version of MSC/NASTRAN.

In addition to acquiring most of the independent NASTRAN vendors, Perna had the company expand its Internet offerings. In February 2000, MSC announced a new Web environment that encompassed its entire product range. This new offering was referred to as MSC.visualNastran and it tied together all the disparate systems the company had developed or acquired as modules under a single framework.

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[10] Federal Trade Commission Consent Decree, October 9, 2001

The company's engineering-e.com Web portal offered Web-based software (e.visualNastran), on-demand licensing for stand alone software, stand alone software (Visionary Design Systems' IronCAD), text books and training. e.visualNastran used the same interface as regular MSC.visualNastran. Users could lease it by the month and results could be stored at the MSC computer site. It was touted as the first analysis program available via an Application Service Provider (ASP). A new MSC.Linux division was created to support several large customers that were already adopting Linux as a sanctioned operating system for Intel-based computers. Many of the MSC programs were subsequently ported to Linux.

In May 2001 MSC.Software announced that it was buying privately held Advanced Enterprise Solutions, Inc. (AES), a major North American CATIA dealer that also sold products from Autodesk and others software vendors as well as computer hardware. MSC agreed to pay $130 million in a combination of cash, shares and notes. One result of the merger was that Dassault, which owned 19 percent of AES ended up owning nine percent of MSC.Software. With this acquisition, the company's annual revenue went over $200 million.

The next major acquisition the company made came in March 2002 when MSC announced that it was acquiring Mechanical Dynamics Incorporated for $120 million in cash as mentioned earlier in this chapter.

One problem with the AES acquisition was that its business, which mostly consisted of reselling hardware and software, was a low margin business and one that could fluctuate substantially quarter to quarter. In May 2002 MSC laid off about eight percent of its staff or 140 people. This brought the headcount down to about 1,500. Revenue continued to fluctuate widely quarter to quarter and in mid-2003 the company announced that it would no longer resell computer hardware, what had been a $20 million per quarter business. This resulted in a $25 million restructuring charge. While the MDI acquisition looked very good, the AES deal was turning into a financial quagmire.

In February 2005 William Weyand replaced Frank Perna as Chairman and CEO of MSC.Software. Then in August, Glenn Wienkoop was hired as president and COO. Both had previously worked for SDRC prior to its acquisition by UGS. Annual revenue in 2006 was about $300 million.

Dick MacNeal was not done with FEA technology just yet. Together with Dr. Harry Schaeffer who had founded Schaeffer Automated Simulation, LLC in May 2000, McNeal founded The MacNeal Group (tMG). Joining them were several experienced FEA development and marketing individuals (Mark Kenyon, Ted Rose and Mike Krauski) each of whom had each spent a number of years at MSC and had earlier joined Schaeffer Automated Simulation. tMG's market focus has been to offer low-cost analysis software built around the original NASA NASTRAN code.

**PDA Engineering (Prototype Development Associates)**

PDA Engineering was established in 1972 as Prototype Development Associates to work on defense and aerospace projects involving materials technology and structural analysis. To support this work, the company began developing software packages, especially software to build models for FEA.

In 1977 the company began to turn this work into a commercial product for mechanical design and analysis. Designed to function as a pre- and post-processor for

FEA programs offered by other companies as well as proprietary packages, the software, PATRAN, was introduced in 1979. In 1980, the company changed its name to PDA Engineering. Gradually, the company's focus shifted from engineering services to software licensing. PDA Engineering went public in 1985.

By 1986, the company's revenues (for the fiscal year that ended June 30th) were $17.4 million of which software represented 56 percent of the total. The company reported 535 commercial PATRAN licenses in use as well as 92 university agreements. The company's president was Dr. John McDonald, one of the company's founders, while the PATRAN activity was run by Louis Crain. Hayden Hamiliton, who previously was with SDRC, was executive director of software development while Jim Newcomb was director of marketing and Rick Caselli was director of sales. Newcomb had previously been with Auto-trol Technology and Dataquest, an industry market research firm, while Caselli had earlier been with Applicon.

Crain was the key person at PDA during PATRAN's formative years. He had a degree in aeronautics and astronautics from MIT and had worked on NASA's Apollo and Skylab projects while employed by McDonnell Douglas. He joined PDA in 1975 and remained with the company until 1989. At various times he was either vice president or president of the PATRAN division.

In 1988, PDA Engineering began development of a new version of PATRAN called PATRAN 3. While earlier versions of the software had been implemented on the basis that the user would interactively create the FEA model either using data imported from a CAD system or geometry created directly by the user, PATRAN 3 was predicated on the assumption that models would be created directly from CAD data.

The company became more aggressive in developing partnership agreements with CAD vendors including EDS/Unigraphics, Dassault Systèmes, PTC and Matra Datavision. PDA referred to this approach as "The Single Geometric Model." A key aspect of the new software was that loads and boundary conditions could be applied to the geometric model and if the geometry of the model changed, the loads and boundary conditions would still be associated with the model.

PATRAN 3 was publicly announced on October 1, 1991 but was not ready for customer delivery until mid-1992. This was a large project that was a ground-up restructuring of the software that implemented a MOTIF-compliant user interface, initially on Sun workstations. PDA provided interfaces to both MSC/NASTRAN and ANSYS as well as FEA software it had developed or licensed from other companies. By 1994, PDA had invested over $35 million developing this software.

The company also offered two other products. One was M/VISION, introduced in 1990, that enabled users to visually review material information contained in either industry databases or information that had been developed internally. The other product was DESIGN/TEAM (Trimmed Element Analysis Method) that used an analysis technique often referred to as the Boundary Element Method. The latter technique differed from the traditional FEA method in that it worked directly with the geometry that described the part. DESIGN/TEAM was conceptually similar to software marketed by Rasna Corporation (which was subsequently acquired by PTC as discussed in Chapter 16). DESIGN/TEAM was renamed P3/TEAM and incorporated into the PATRAN 3 product in early 1994.

PDA's business seemed to be on a roll until mid-1993. In August 1993, the company announced that its earnings for the $4^{th}$ fiscal quarter of 1993 which ended that June $30^{th}$ had dropped to $0.10 per share from $0.17 the prior year. The price of the company's stock dropped from $11 per share earlier in 1993 to $3.75 after the announcement. One result of PDA's changing fortunes was the only criminal conviction I am aware of involving investments in a CAD industry company.

Richard J. Smith was vice president of North American sales for PDA at the time. He had previously been employed at Auto-trol Technology in sales and marketing. In mid 1993 he became aware of the company's revenue shortfall for the quarter and the adverse impact that would have on $4^{th}$ quarter earnings. He proceeded to sell over 50,000 shares of PDA stock and sold short another 35,000 shares. In addition, he provided this non-public information to a close friend, Angela Bravo de Rueda and his father, David Smith.

The Securities and Exchange Commission filed a complaint in September 1995 based on a voice mail message Smith had left for several other PDA employees. This voice mail message was heard by another employee, Linda Grove, who for some reason was listening to other employees voice mail. She forwarded the message to her own voice mail box and recoded it. She then disclosed this message to PDA management which led to an SEC investigation. The SEC claimed that Smith had made over $120,000 in illegal profits from his actions.

In March 1995 the SEC enjoined Smith from further violation of federal security laws. This was followed by a criminal conviction in 1996 at which time he was sentenced to serve 15 months in prison and pay over $95,000 in restitution and fines. As far as I could determine neither his father nor friend were prosecuted.

The downturn in PDA's sales led to losses in fiscal 1994 and eventually to the company's acquisition by MacNeal Schwendler Corporation in August 1994 for $6.85 per share or a total of $56 million. At the time, PDA's sales were running at about $42 million per year.

**Structural Research & Analysis Corporation**

Structural Research & Analysis Corporation (SRAC) was founded in Los Angeles in 1982 by Dr. Victor Weingarten a professor at the University of Southern California and the head of its civil engineering department. The company's early software was mainframe oriented but by 1985, SRAC's focus had switched to personal computers and engineering workstations. As I wrote in Engineering Automation Report in November 1995, it took a great deal of foresight to realize in the mid-1980s the impact desktop computers would have on engineering design.[11]

Throughout the 1980s, SRAC launched several versions of COSMOS, its flagship FEA package. The company grew slowly as it focused on its software development efforts. At one time the company offered a version of its COSMOS software on the Apple Macintosh but soon decided to concentrate on MS/DOS PCs and UNIX workstations.

In the mid-1990s SRAC began developing closer working relations with the companies producing a new class of mid-range CAD software packages including Bentley Systems, SolidWorks, Intergraph and Autodesk. The intent was to provide design engineers with sufficient FEA technology that they could perform first level analyses on the parts and assemblies they were designing. The first such collaboration was with

[11] *Engineering Automation Report*, November 1995, Pg. 6

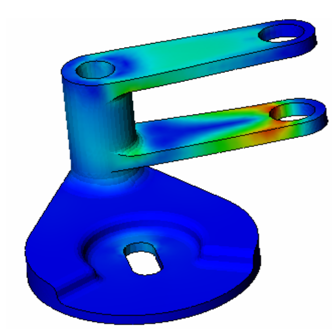
Bentley Systems. This resulted in a package called COSMOS/M DESIGNER II in 1995 followed by COSMOS/Works in 1996 with SolidWorks.

In addition to creating the ability to work directly with CAD geometry, SRAC programmers spent a substantial amount of effort creating fast algorithms for solving FEA problems. The company's flagship code in this area was simply called FFE for Fast Finite Element.

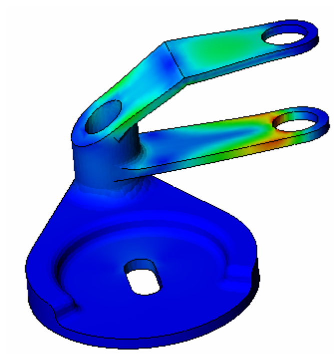
By 1998, COSMOS users were processing surprisingly complex FEA models on Pentium II PCs. One example was Nichols Aircraft which manufactured lubricating oil pumps for the jet engine industry. With the help of SRAC's consulting staff, Nichols engineers created a complete FEA model of a pump casting with approximately 1.3 million degrees of freedom in three to four days. First order solutions on a PC took less than two hours to run. Just a few years earlier, most analysts would not have attempted a problem this size on anything less than a mainframe or expensive high-end server.[12]

At the same time, SRAC was developing new software using UGS's Parasolid solids modeling technology that would enable users to directly build FEA models from packages such as SolidWorks, Solid Edge and MicroStation Modeler, all of which also used Parasolid. This technology was called DesignSTAR and was intended to facilitated linear static and dynamic analysis as well as thermal analysis. The first actual product to use this technology was called COSMOS/Edge 3.0 which worked with Solid Edge. It was priced starting at $5,000.

In 1999, SRAC introduced COSMOS/Works 5.0 which could be embedded in SolidWorks 99. This enabled users to design parts and assemblies and to analyze them in a continuous operation without the need to translate data from one package to another. The software included a new meshing capability called AccuStress that automatically changed the density of elements in areas where higher stresses could be expected. Previously, this was a time-consuming manual process and not one design engineers were particularly good at. Cosmos/Works could also be used to optimize the shape of parts.



Initial design



Optimized design

Figure 22.6
Use of COSMOS/Works 5.0 to optimize the shape of parts

The relation between SRAC and SolidWorks became increasingly close in subsequent years and in March 2001, Dassault Systems acquired SRAC for $22 million in stock and eventually made it part of the SolidWorks operation. Initially Barbara

[12] *Engineering Automation Report*, September 1998, Pg. 4

Guerra, Victor Weingarten's daughter and vice-president of sales and business development at SRAC and, became CEO of the new subsidiary. Dr. Vasu Chavakula, vice-president of engineering and Lih Wu, the company's CFO and director of international sales remained in similar positions under Dassault ownership. President and CEO Dr. Victor I. Weingarten, SRAC's founder, served for a period of time in a consulting capacity.[13]

In December 2001, SRAC introduced a new package, COSMOSMotion, that integrated MDI's motion analysis software with SRAC's structural analysis software. The resultant package worked closely with SolidWorks so that users had only one interface to work with.

**Tektronix**

Several companies, particularly McDonnell Douglas Automation (McAuto), Boeing Computer Services and Structural Dynamics Research Corporation (SDRC) offered either time-sharing services or software packages for handling the creation of finite element models, formatting the data for analysis and displaying results. The McAuto software targeted civil engineering users while the other were more focused on mechanical engineers.

The biggest problem with time-sharing solutions was that the terminal had to be continually connected to the main computer system over links that were 2,400 bps at best. The terminals available at the time had very little local intelligence. Since the typical model involved a substantial amount of data, simply tasks such as rotating the model to a new orientation were quite time consuming since the entire image had to be retransmitted by the host computer. In addition, time-sharing was fairly expensive if an outside commercial service was being used.

In 1976 I was the manager of market development for Tektronix's Information Display Systems division. The company had recently introduced the 4081 graphics system which could function as either a stand-alone computer or as a terminal to a larger computer. Some people have referred to it as the world's first graphics workstation. The 4081 consisted of a 19-inch storage tube display and an Interdata 16-bit minicomputer.

We decided to create a 4081 program that would handle the creation of FEA models. This project was assigned to a very good software developer, Jeff Gingerich, who, over time, was assisted by Marv Abe, Gary Romans, and others. Although it probably had a different name at the start, this system, which included both the 4081 hardware and the software, became known as the FEM181.

The intent was to create a 4081 software package that would enable a user to interactively build a FEA model completely off line and would require connection to the computer being used for analysis simply to upload the completed model and download results. The FEM181 system did not include post-processing software as such but the general graphics capabilities of the 4081 could be used for this function if the user organization wanted to write that software. Models could be created in three different modes - existing model data could be downloaded from a host computer and edited, element data could be entered by digitizing drawings or elements could be created interactively.

[13] *Engineering Automation Report*, May 2001, Pg. 6

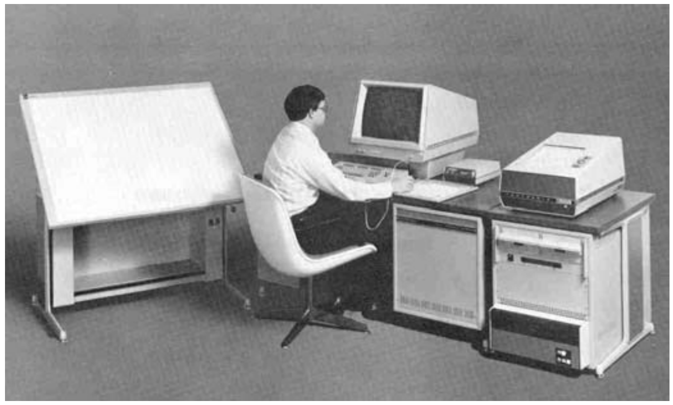


Figure 22.5
Tektronix FEM181 System with Jeff Gingerich at the console

Downloading existing data was important since many potential users already had models that had been created using traditional methods and wanted to use the FEM181 to edit and update that data. I am not sure how it came about, but Jeff and I came up with the idea of being able to graphically shrink each element when it was being displayed without actually changing the model data. When a model is displayed, elements that are adjacent share common boundaries. If an individual element was missing, the user might not realize that fact because all the edges appeared to be displayed. By shrinking every element towards its center, gaps would appear between elements. A missing element would jump right out at the user.

When the system was demonstrated to Chrysler, a finite element model of a automobile hood was downloaded to the FEM181 system. The applications engineer doing the demonstration did a shrink operation on the model and the manager in charge of the Chrysler analysis department took one look at it and said “So that’s why we have been getting poor results with this model.” Right in the middle of the model was a missing element. It was not obvious in plots of the input data but it caused the FEA program to produce erroneous results. Within a few years, virtually all FEM packages incorporated this capability.

The FEM181 was launched in the summer of 1977. Over the next several years probably 20 systems were sold and installed. Some of these were used well into the 1980s. Tektronix withdrew from the systems business in late 1979 and other companies such as PDA Engineering (now part of MSC.Software) began offering comparable software.

# Appendix A

## Terminology

| | |
|---|---|
| AEC | Architecture, Engineering and Construction |
| APT | Automatically Programmed Tool |
| Batch Mode | Computer execution of submitted jobs in a sequential manner |
| bit | Smallest unit of data manipulated by a computer system |
| bpi | Bits per inch – typically in regards to magnetic tape |
| bps | Bits Per Second |
| Bps | Bytes Per Second |
| Byte | Eight bits unit of data or memory |
| CAD | Computer-Aided Design or Drafting |
| CAE | Computer-Aided Engineering |
| CAM | Computer-Aided Manufacturing |
| CPU | Central Processing Unit – the main logic unit of a computer |
| CRT | Cathode Ray Tube such as used in TVs and computer monitors |
| Database | A method of storing computer data in an organized manner |
| Digitizer | Device for converting information on paper to a digital format |
| FEA | Finite Element Analysis |
| FEM | Finite Element Modeling – also known as Finite Element Mesh Generator |
| GB | Billions of Bytes |
| IGES | Initial Graphic Exchange Specification |
| KB | Thousand of Bytes (actually 1024) |
| Layer | Method separate drawing data by type |
| Light Pen | CRT display input device that senses light as item is displayed |
| Macro | Method of combining multiple individual commands into a single Command |
| Mainframe | Term used to define large computer typically used in a batch mode |
| MB | Millions of Bytes |
| MHz | Millions of clock cycles per second |
| MIPS | Million of Instructions Per Second |
| MIT | Massachusetts Institute of Technology |
| NC | Numerical Control |
| Node | A specific computer or other device in a network |
| NURBS | Non-Uniform Rational B-Splines |
| PADL | Part & Assembly Description Language (University of Rochester) |
| PC | Personal Computer |
| P&ID | Process and Instrumentation Diagram |
| Post Processor | Software that converts an NC program's output to work with a specific machine tool |
| Turnkey | All components of a system, hardware and software, are sold by a single vendor |
| UNIX | Operating system originally developed at Bell Laboratories |

| | |
|---|---|
| Windows | Microsoft operating system for PCs |

# Appendix B

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