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

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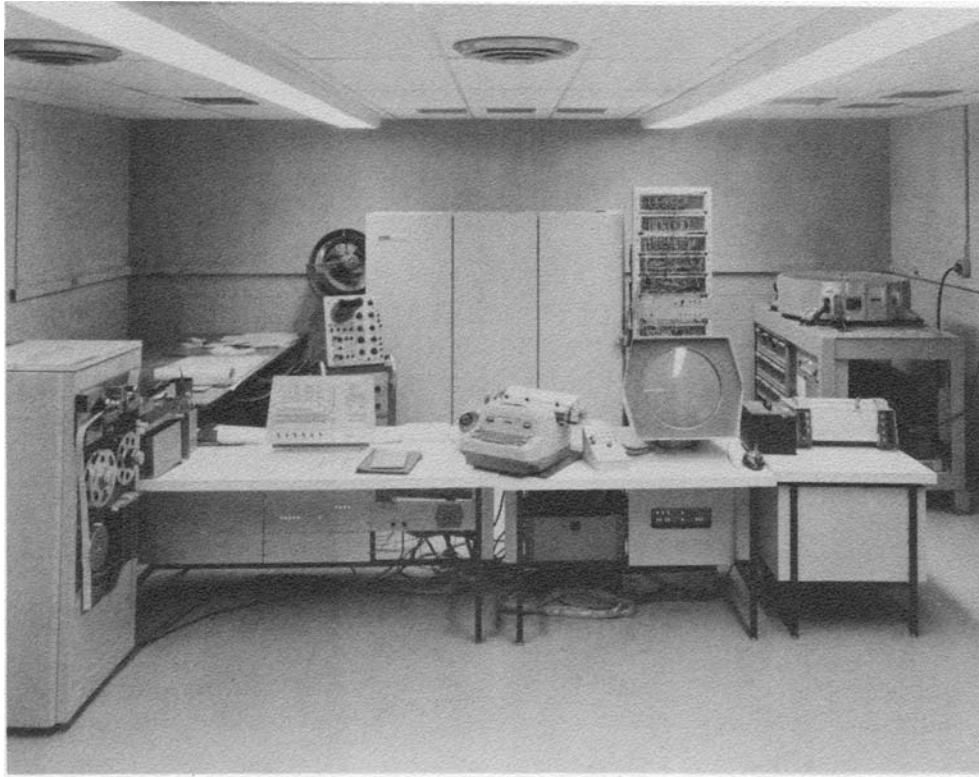
Figure 6.1
Prototype EDM configuration
(From left to right: In background – fan to keep computer cool, Tektronix oscilloscope, Digital PDP-1 computer, Itek-built display logic and Telex disk drive. In foreground – paper tape reader/punch, computer console, console typewriter, control buttons, CRT display,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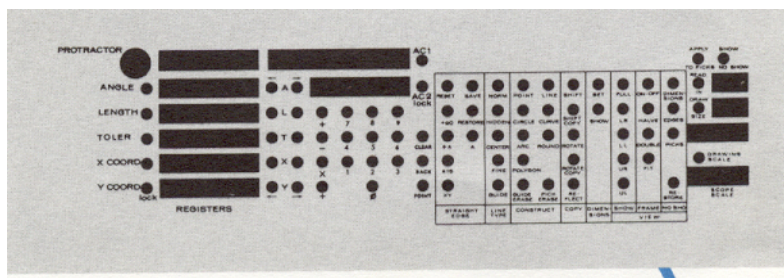

Figure 6.2
EDM Light Button Menu Overlay

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*.)
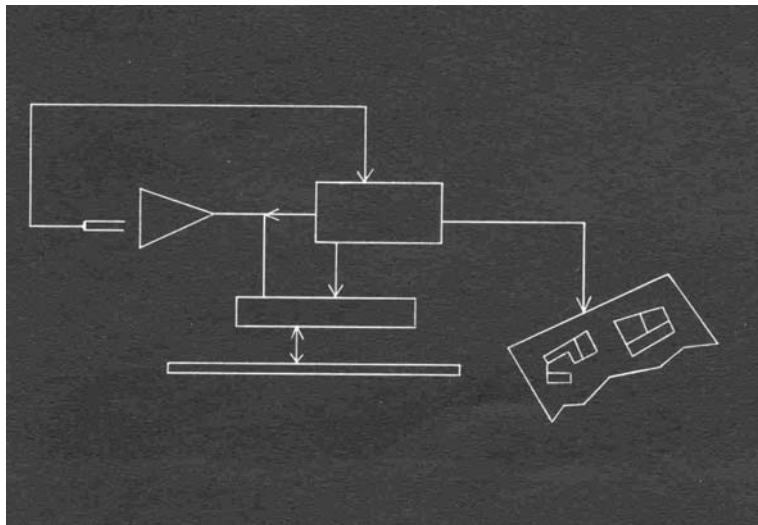

Figure 6.3
Early EDM drawing

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.
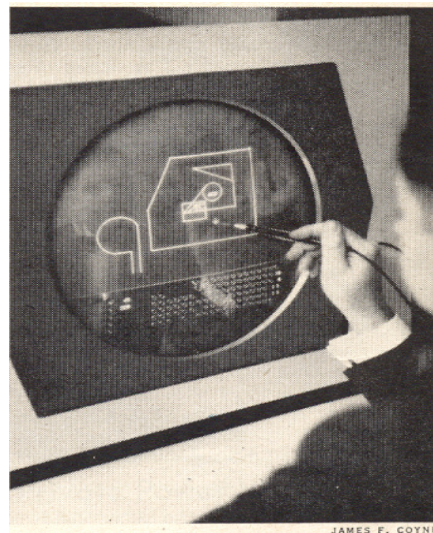

Figure 6.4
Time illustration showing Jack Gilmore with light pen and control button overlay[4]

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[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.

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