Wayne Carlson

# History of Computer Graphics and Animation

THE OHIO STATE UNIVERSITY

# Computer Graphics and Computer Animation: A Retrospective Overview

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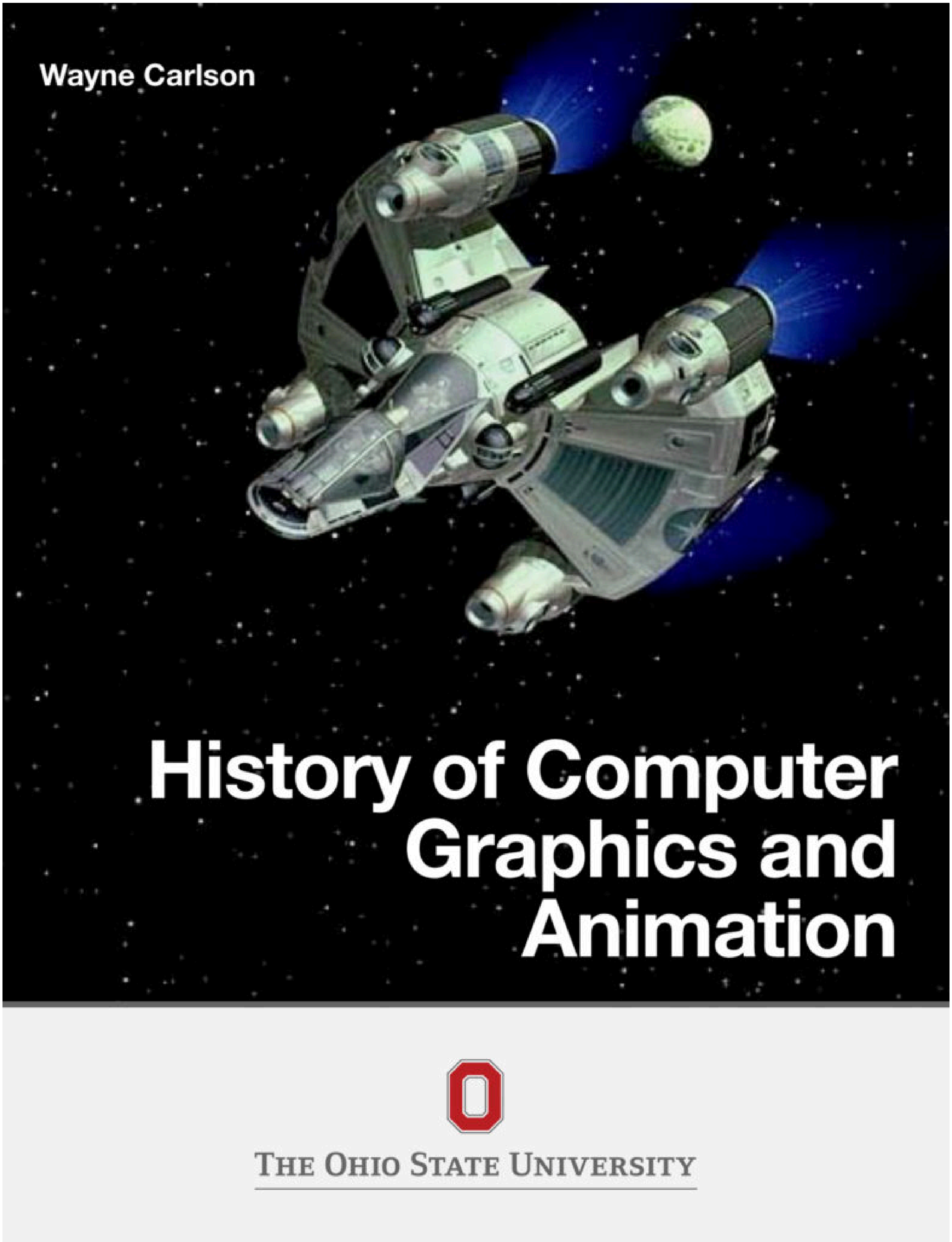

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# Opening Animation

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/HistoryCG-1-1.m4v

ACM SIGGRAPH premiered the feature length documentary, “The Story of Computer Graphics,” on Sunday, 8 August 1999, at the Shrine Auditorium in Los Angeles to kick off the SIGGRAPH 99 conference. Mastered in HD, the film includes historical graphics and visual elements, and features behind-the-scene interviews with over 50 pioneers in the industry. Carl Machover and John Hart were Executive Producers, Steve Silas, Producer, Frank Foster, Director, Joan Collins, Co-Producer, and was written by Judson Rosebush.

*Note: Front cover photo produced by Digital Productions (see Chapter 6).*

# Chapter 1: The history of early computing technology

# The history of early computing technology

Early contributions to computation influenced the development of graphics technology. This chapter addresses some of the more important of these contributions.

*Radiosity Factory, Cornell University – 1988*

The study of the history of CGI (computer generated imagery) is an important part of our overall educational experience, not necessarily to build on the historical precedent, but to gain an understanding of the evolution of our discipline and to gain a respect for the key developments that have brought us to where we are. The discipline is so recent in its early developments and so rapidly changing that we are in fact living it, and it evolves as we speak. Yet we have been so busy in advancing the discipline that we have often neglected to accurately record this history. So we will decide to agree upon certain past events in order to begin to develop a definitive record of what has transpired in this evolutionary process.

We must learn from the past, as we develop a theory and methodology which is tuned to the capabilities and qualities inherent in software, hardware, animation techniques, etc. that are part of our broad, contemporary, and creative computer graphics environment. It is in this context that this e-book has been developed.

Herbert Freeman, in an introduction to his 1980 IEEE compilation of computer graphics papers, presents a succinct overview of the first two decades of the development of the CGI discipline.[1] Like many other disciplines, computer graphics and animation has a rich (albeit relatively short) history that involves the following four eras, which are very much linked and related:

1. pioneers
2. innovators
3. adapters
4. followers

Early pioneers include artists (such as Chuck Csuri and John Whitney) and researchers (such as Ivan Sutherland and Ken Knowlton). These visionaries saw the possibilities of the computer as a resource for making and interacting with pictures, and pushed the limits of an evolving technology to take it where computer scientists never imagined it could go. Their work motivated the work of the others as they tried to realize the potential of this new vision. In this book, we will survey work from Sutherland, Csuri and Whitney, National Research Council of Canada (Burtnyk, Wein and Foldes), Michael Noll, Lillian Schwartz and Ken Knowlton, and others.

Many of the so-called innovators were housed in universities and research labs, and were working toward solving fundamental problems of making “pictures” of data using the computer. We will survey work from many of these facilities, including Bell Labs, Ohio State, University of Utah, New York Institute of Technology, Evans & Sutherland and several aerospace and automotive companies, MIT, and others. Individual work of Nelson Max, Jim Blinn, Loren Carpenter, Turner Whitted, and others will also be reviewed.

The early adapters included pioneering CGI production facilities, artists, researchers, and research labs and industries with an interest in converting much of this early work into a viable (and marketable) tool for realizing their disparate goals. Notable companies include Robert Abel and Associates, Digital Effects, MAGI, Information International Inc., and others. Artists include more from Whitney Sr., Yoichiro Kawaguchi, David Em, and others.

The late seventies and early eighties saw the second wave of adapters, which were primarily special effects production companies, equipment and software developers, universities, motion picture companies, etc. We will

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[1] Tutorial and Selected Readings in Interactive Computer Graphics, IEEE computer Society tutorials, Herbert Freeman, IEEE Computer Society, 1980

survey work from Pacific Data Images, Cranston/Csuri Productions, Digital Productions, Omnibus Computer Graphics, Bo Gehring, and others.

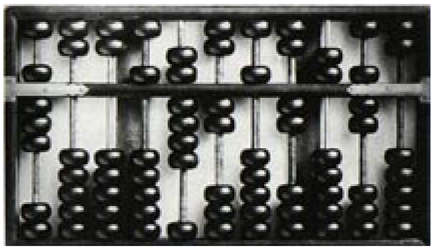
As the technology advanced and the acceptance of this new approach to image making increased, the industry likewise evolved, and many of the current contributors, or followers (this descriptor is not intended to be demeaning or derogatory) came into being. These include effects production companies such as Pixar, Disney, Metrolight, Rhythm and Hues, ILM, Xaos, and others. We will also look at work from universities such as Cal Tech, Cornell, Ohio State, UNC, University of Illinois-Chicago, etc., and companies and research labs such as Apple, Sun, Xerox, SGI, Microsoft, Alias, Softimage, and others. We will look at the impact on related areas, such as HCI, design, multimedia, virtual reality, scientific visualization, etc.

# 1.1 Early analog computational devices

In order to adequately discuss the beginnings of computer graphics, we need to step back further in history and investigate a number of contributions that influenced the way we do things. Some of the innovations still are used in one form or another today.

http://www.computerhistory.org/timeline/

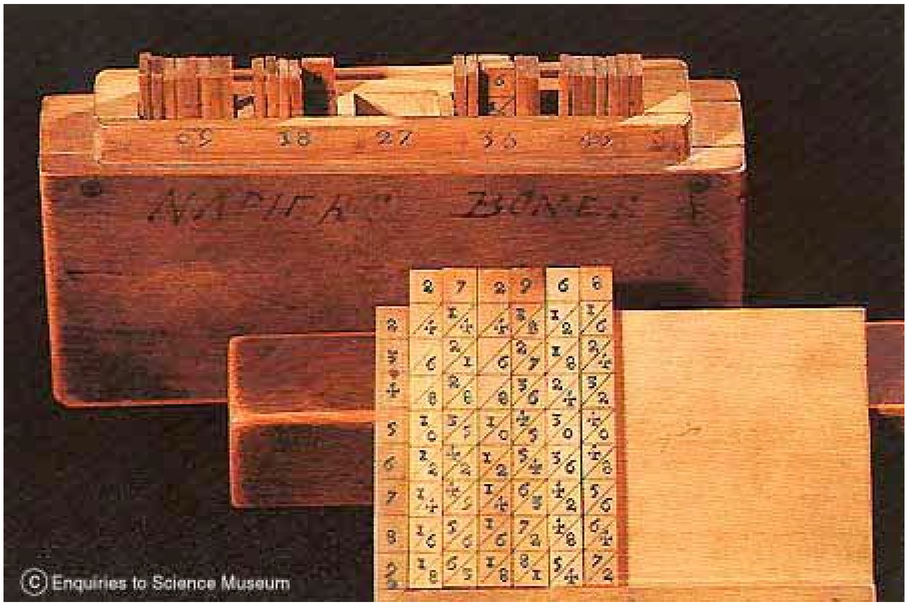
## The Abacus



Computing or calculating instruments date back to the abacus, used by early man to represent a positional counting notation that was used in counting tables, called abaci. They were really not calculators per se, but provided a technique to keep track of sums and carries in addition. Although the abacus existed as far back as 5 A.D. the abacus as we know it was attributed to the Chinese in 1200 AD.

## Napier's Bones

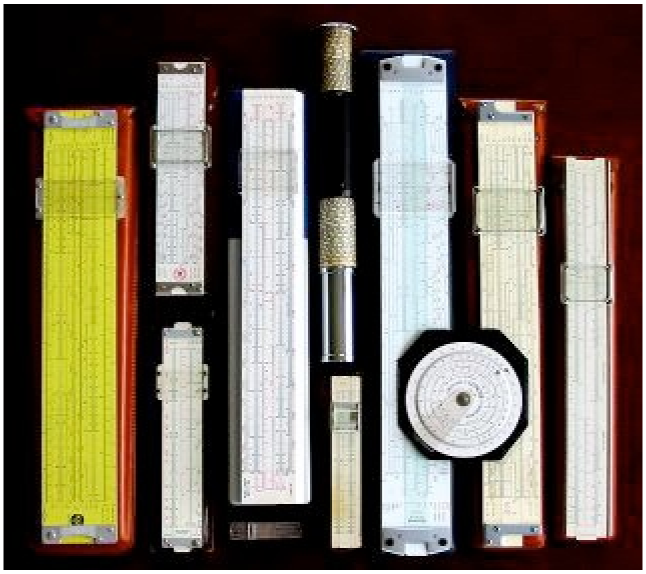
John Napier in 1617 introduced a calculation aid for multiplication, called Napier's Bones. They consist of a set of wooden rods, each marked with a counting number at the top, and multiples of that number down the lengths of the rods. When aligned against the row of multiples as shown in the photo below, any multiple of the top number can be read off from right to left by adding the digits in each parallelogram in the appropriate row. Multiplication is thus reduced to addition.



Napier's Bones – An aid to multiplication, they reduce the problem to one of addition. For example, consider the bones shown here. In order to multiply 6 (horizontal) with 96 (adjacent vertical rods), look at the four cells in the intersection. By adding the numbers in the diagonal cells, from left to right, we compute the answer. (The first cell, corresponding to the 1s digit, is 6; the middle two cells, corresponding to the 10s digit, are 3 and 4, which sum to 7; the next cell, corresponding to the 100s digit is 5; so 6×96=576)
Source: http://www.sciencemuseum.org.uk

## Slide Rule

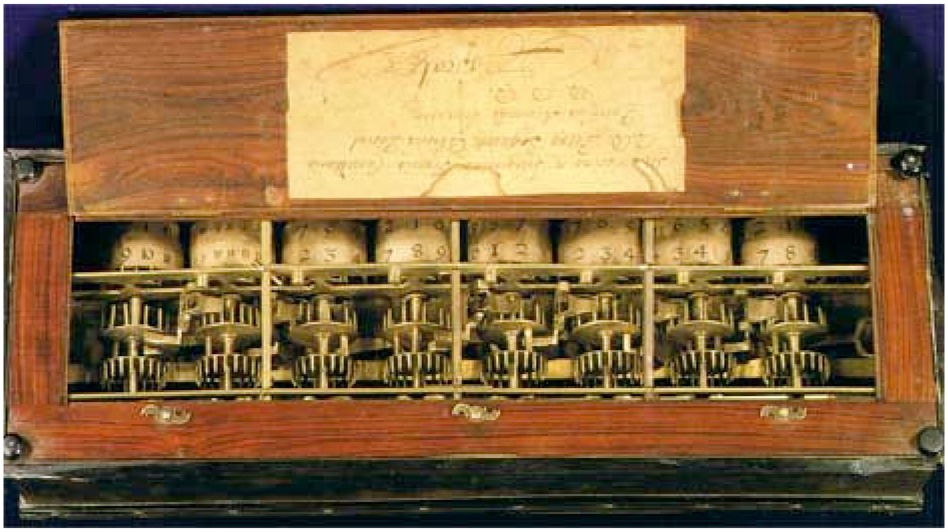
With a goal of simplifying calculations, Napier also introduced the logarithm, which was used in the first slide rule developed by Reverend William Oughtred in approximately 1622. Oughtred also was the first to use the "x" as the symbol for multiplication. Eric Marcott has an excellent website devoted to the slide rule, including operating instructions for various models.



*Collection of Slide Rules*
*Source: http://www.sliderule.ca/index.shtml*

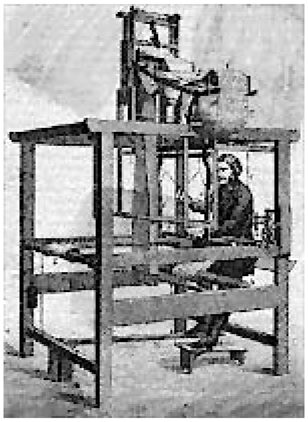
## Pascalene adder

Several automatic mechanical "calculators" were built in the 1600s, including the Schickard implementation of Napier's Bones, the Pascalene automatic adder, and the Liebniz automatic multiplier. Each of these devices was considered an "**analog**" device.



*Pascalene Adder*
*Source: http://history-computer.com*

## 1.2 Early digital computational devices



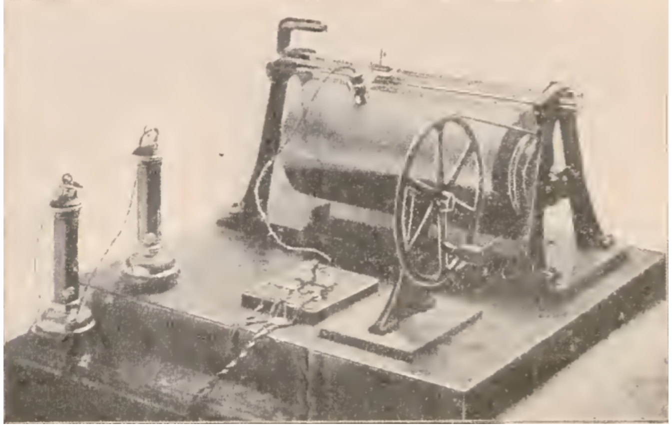
*Jacquard Loom*

Alternatively, most modern computational devices are "**digital**". One of the earliest implementations of a digital system is attributed to Joseph-Marie Jacquard of France in 1801, the Jacquard Loom. He used a punched card to control the weaving actions of a loom, which introduced much more intricate patterns in woven cloth. Jacquard's approach was a variation on the original punched-card design of Jacques de Vaucanson in 1745. de Vaucanson was a toy maker (most famous for his mechanical duck), and his idea of automating the weaving process was not well accepted by weavers (a situation not unlike that of the modern day computer ink and paint process in traditional animation.)

The punched-card idea was adopted later by Charles Babbage in about 1830 to control his Analytical Engine, and later by Herman Hollerith for tabulating the 1890 census. The Babbage Analytical engine (which was never completed by him) was designed to use Jacquard's punched cards to control an automatic calculator, which could make decisions based on the results of previous computations. It was intended to employ several features later used in modern computers, including sequential control, branching, and looping.

An assistant to Babbage was Augusta Ada Lovelace (or Lady Lovelace), the daughter of the English poet Lord Byron, and a mathematician, who created a "program" for the Analytical Engine to compute a mathematical sequence known as Bernoulli numbers. Based on this work, Ada is now credited as being the first computer programmer and, in 1979, a modern programming language was named ADA in her honor.
From: http://www.agnesscott.edu/lriddle/women/love.htm

In 1878, Oberlin Smith devised a crude magnetic recording device made of a silk thread covered with steel dust. In theory, when exposed to a magnetic field, the steel dust particles would align with the magnet, creating a digital pattern. Smith applied for a patent, but never followed through with the application. He concluded that he wouldn't be able to establish a useful pattern on the strings, published his results in 1888, but dropped his investigations.



*Telegraphone*

In 1898, inventor Valdemar Poulsen of Denmark filed a patent for a "…method of, and apparatus for, effecting the storing up of speech or signals by magnetically influencing magnetisable [sic] bodies". His idea was that a wire, when touched with an electromagnet at different points and times, would store a signal that later could be retrieved to recover the same energy that caused the magnetization in the first place. He developed his idea as a "telephone answering machine" called the Telegraphone and started a company to market it. Another of Poulsen's devices can be considered to be the original version of the hard disk. It consisted of a 4.5 inch diameter steel disk with a raised spiral on the surface which was traced by the electromagnet as the disk rotated, magnetizing the disk in the same fashion as the wire. [1]

Further contributions to magnetic recording were few, until Fritz Pfleumer developed the magnetic tape, which was a strip of paper covered with magnetic dust (the first paper tape used was covered with high grade ferric oxide barn paint (rust red), and a cloud of red dust sprayed the air as the tape was used). The German General Electric company bought the patents from Pfluemer and marketed the first true tape recorder, the Magnetophon (meaning "tape recorder" in French) in 1936.

The U.S. Census Bureau was concerned about the difficulty of tabulating the 1890 census. One of its statisticians, Herman Hollerith, envisioned a machine that could automate the process, based on an idea similar to that used in the Jacquard Loom. Hollerith designed punches for his system, which he called the Hollerith Electric Tabulating System. A pin would go through a hole in the census card to make an electrical connection with mercury placed beneath. The resulting electrical current activated a mechanical counter and the information would be tabulated. The tabulating system was featured in an 1890 issue of ?Scientific American magazine.

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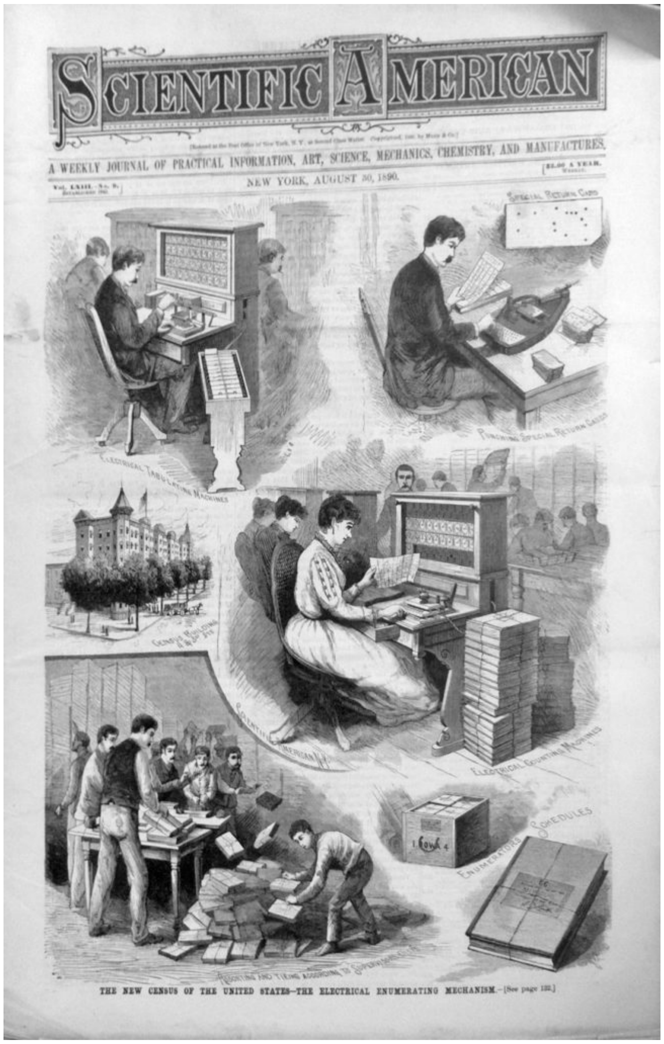
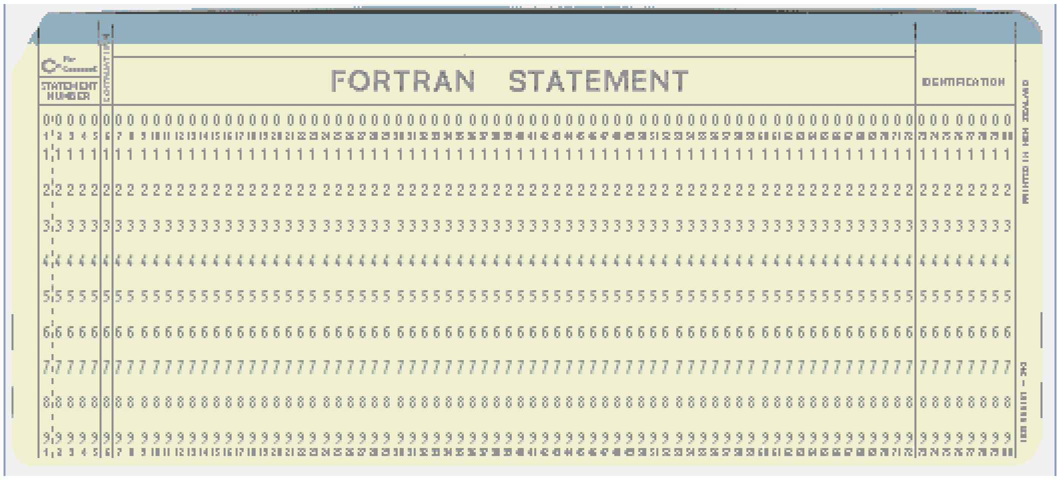
[1] Reference: http://www.computerhistory.org/storageengine/poulsen-records-voice-on-magnetic-wire/;
Image source: Popular Science Monthly, May-Oct 1901, page 414



*1890 Scientific American cover*

The 80 column punch card introduced by Hollerith in 1928 became the standard input medium for computers until the late 1970s when interactive systems became usable. It was sized at 7 3/8 inches wide by 3 1/4 inches high by .007 inches thick. Prior to 1929, this was a standard size for many U.S. banknotes, and Hollerith apparently chose it so that he could store cards in boxes made for the Treasury Department.



*"IBM" Card*

What became known as the "IBM card" was the source of a popular phrase which became the topic for a great article by Steven Lubar of the Smithsonian in 1992, titled "*Do not fold, spindle or mutilate: A cultural history of the punch card*."[2]

Hollerith obtained over 30 patents for his research, but he was not a marketer. He felt he had a choke hold on the census tabulating machine, and he charged the Census Bureau more than it would have cost to do it by hand. As a result, they developed, and in fact patented their own version of the machine. Hollerith almost closed the doors on his company, but he was able to attract a brilliant business mind, Thomas J. Watson, to run it, and his company survived; it would later become International Business Machines (IBM).

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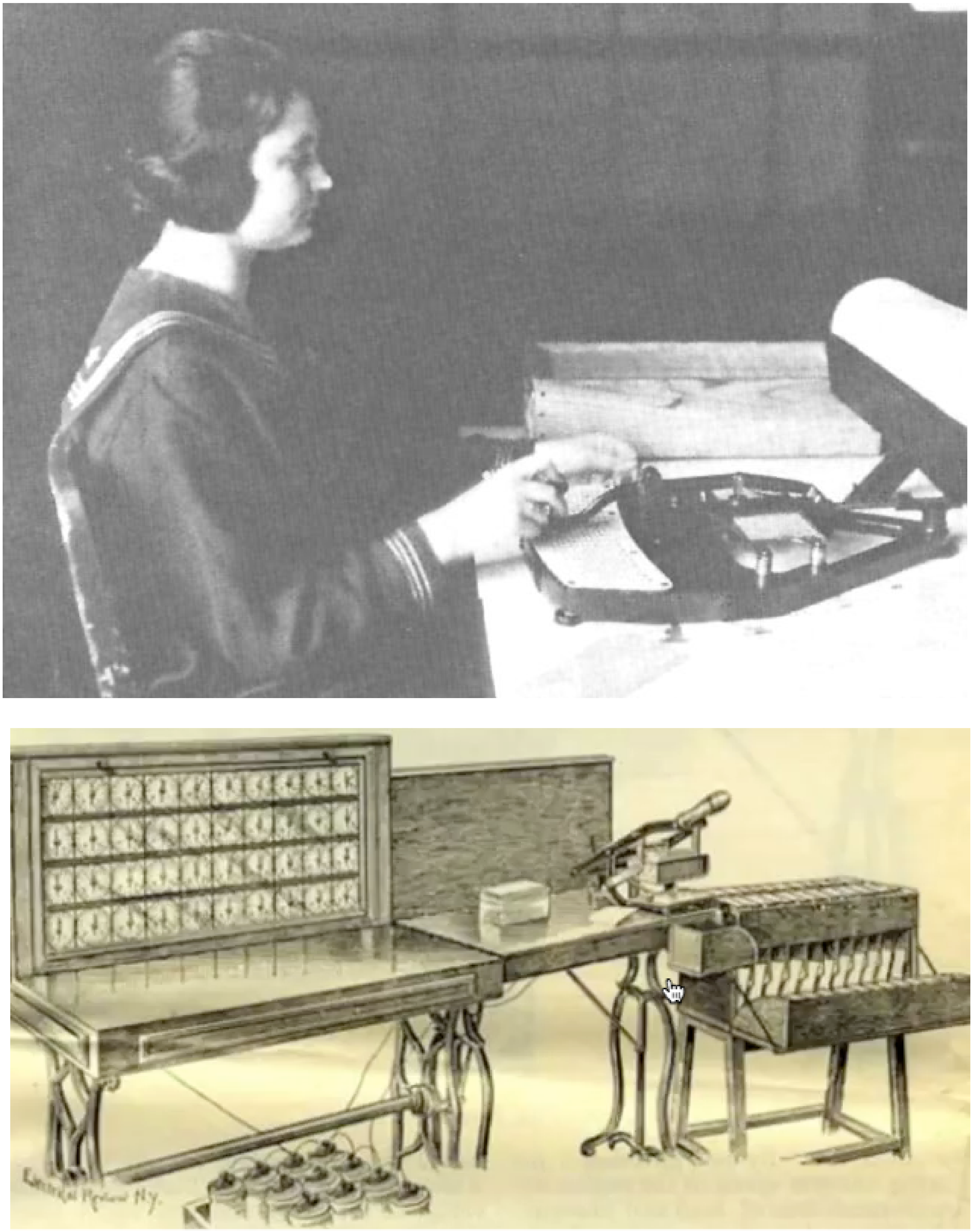
[2] "Do Not Fold, Spindle or Mutilate: A Cultural History of the Punch Card", Steven Lubar, Journal of American Culture, Volume 15, ?Issue 4, pages 43–55, Winter 1992



*The Hollerith Tabulating Machine*

Definitions:

**Analog**: relating to, or being a device in which data are represented by continuously variable, measurable, physical quantities, such as length, width, voltage, or pressure; a device having an output that is proportional to the input.

**Digital**: A description of data which is stored or transmitted as a sequence of discrete symbols from a finite set, most commonly this means binary data represented using electronic or electromagnetic signals.

Ref: http://dictionary.com

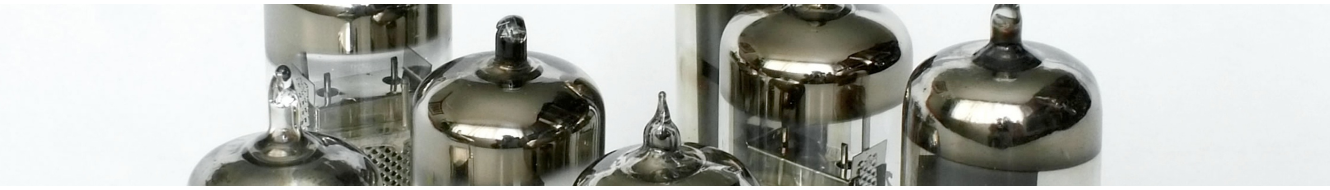
http://www.columbia.edu/acis/history/jacquard.html

http://www.swarthmore.edu/Humanities/pschmid1/essays/pynchon/vaucanson.html

http://www.cs.uiowa.edu/~jones/cards/history.html

?http://www.computerhistory.org/revolution/punched-cards/2

# 1.3 Electronic devices



The turn of the century saw a significant number of electronics-related contributions. One of the most significant was the vacuum tube, invented by Lee de Forest in 1906. It was an improvement on the Fleming tube, or Fleming valve, introduced by John Ambrose Fleming two years earlier. The **vacuum tube** contains three components: the anode, the cathode and a control grid. It could therefore control the flow of electrons between the anode and cathode using the grid, and could therefore act as a switch or an amplifier. A PBS special on the history of the computer used monkeys (the cathode) throwing pebbles (the electrons) through a gate (the grid) at a target (the anode) to explain the operation of the triad tube.

**Movie 1.1** Simulation of a Vacuum tube

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/monkeysVIDEO_T1-1.m4v

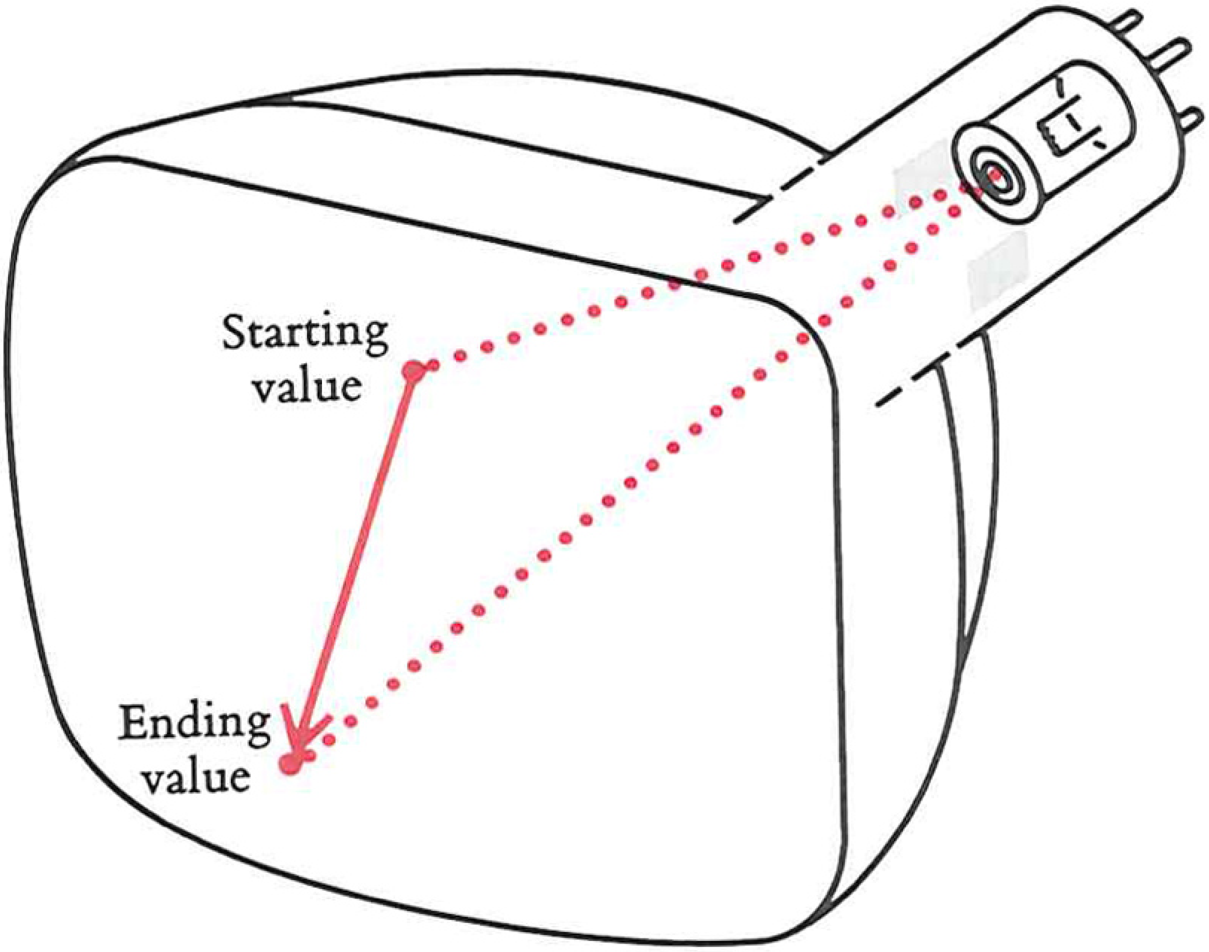
*with Host Ira Flatow, from PBS "Transistorized!" http://www.pbs.org/transistor/science/events/vacuumt.html*

http://www.nobel.se/physics/educational/integrated_circuit/history/
http://www.pbs.org/transistor/album1/addlbios/deforest.html

Engineers were interested in the functionality of the vacuum tube, but were intent on discovering an alternative. Much like a light bulb, the vacuum tube generated a lot of heat and had a tendency to burn out in a very short time. It required a lot of electricity, and it was slow and big and bulky, requiring fairly large enclosures. For example, the first digital computer (the ENIAC) weighed over thirty tons, consumed 200 kilowatts of electrical power, and contained around 19,000 vacuum tubes that got very hot very fast, and as a result constantly burned out, making it very unreliable.

*Vacuum tube and transistor*

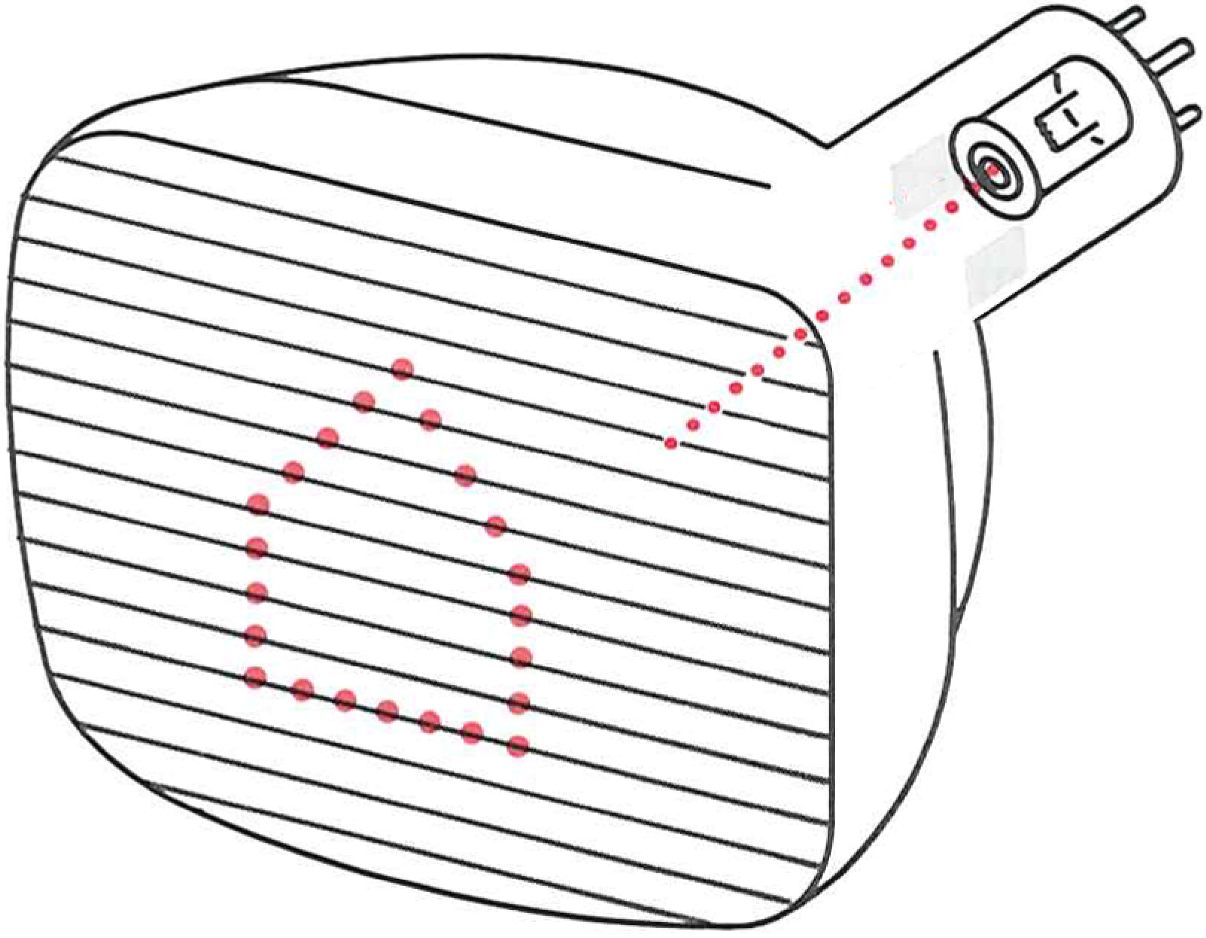
A special kind of vacuum tube was invented in 1885. Called the **Cathode Ray Tube** (CRT), images are produced when an electron beam generated by the cathode strikes a phosphorescent anode surface. The practicality of this tube was shown in 1897, when German scientist Ferdinand Braun introduced a CRT with a fluorescent screen, known as the cathode ray oscilloscope. The screen would emit a visible light when struck by a beam of electrons.



*Cathode Ray Tube – Vector display*

This invention would result in the introduction of the modern television when Idaho native **Philo Farnsworth** introduced the image dissector in 1927, and the first 60 line "**raster-scanned**" image was shown (it was an image of a dollar sign.) Farnsworth has been called one of the greatest inventors of all times, but he suffered for a long period of time in obscurity because of an unfortunate set of circumstances. RCA challenged the patents that Farnsworth received in 1930 for the technology which was the television, and although he won the litigation, it took so long that his patents expired and RCA maintained a public relations campaign to promote one of their engineers as the actual inventor (see sidebar below.)

Variations of the CRT have been used throughout the history of computer graphics, and it was the graphics display device of choice until the LCD display was introduced 100 years later. The three main variations of the CRT are the vector display, a "**storage tube**" CRT (developed in 1949), and the **raster** display.



*Cathode Ray Tube – Raster display*

For more information: http://entertainment.howstuffworks.com/tv3.htm

The following text is from Time Magazine’s accounting of the 100 great inventors of all time:

> “As it happens, [Vladamir] Zworykin had made a patent application in 1923, and by 1933 had developed a camera tube he called an Iconoscope. It also happens that Zworykin was by then connected with the Radio Corporation of America, whose chief, David Sarnoff, had no intention of paying royalties to [Philo]Farnsworth for the right to manufacture television sets. “RCA doesn’t pay royalties,” he is alleged to have said, “we collect them.”
>
> And so there ensued a legal battle over who invented television. RCA’s lawyers contended that Zworykin’s 1923 patent had priority over any of Farnsworth’s patents, including the one for his Image Dissector. RCA’s case was not strong, since it could produce no evidence that in 1923 Zworykin had produced an operable television transmitter. Moreover, Farnsworth’s old [high school] teacher, [Justin]

Tolman, not only testified that Farnsworth had conceived the idea when he was a high school student, but also produced the original sketch of an electronic tube that Farnsworth had drawn for him at that time. The sketch was almost an exact replica of an Image Dissector.

In 1934 the U.S. Patent Office rendered its decision, awarding priority of invention to Farnsworth. RCA appealed and lost, but litigation about various matters continued for many years until Sarnoff finally agreed to pay Farnsworth royalties.

But he didn't have to for very long. During World War II, the government suspended sales of TV sets, and by the war's end, Farnsworth's key patents were close to expiring. When they did, RCA was quick to take charge of the production and sales of TV sets, and in a vigorous public-relations campaign, promoted both Zworykin and Sarnoff as the fathers of television."
Ref: http://www.time.com/time/time100/scientist/profile/farnsworth.html? and
http://www.farnovision.com/chronicles/

The specter of World War II, and the need to calculate complex values, e.g. weapons trajectories and firing tables to be used by the Army, pushed the military to replace their mechanical computers, which were error prone. Lt. Herman Goldstine of the Aberdeen Proving Grounds contracted with two professors at the University of Pennsylvania's Moore School of Engineering to design a digital device. Dr. John W. Mauchly and J. P. Eckert, Jr., professors at the school, were awarded a contract in 1943 to develop the preliminary designs for this electronic computer. The ENIAC (Electronic Numerical Integrator and Computer) was placed in operation at the Moore School in 1944. Final assembly took place during the fall of 1945, and it was formally announced in 1946.

The ENIAC was the prototype from which most other modern computers evolved. All of the major components and concepts of today's digital computers were embedded in the design. ENIAC knew the difference in the sign of a number, it could compare numbers, add, subtract, multiply, divide, and compute square roots. Its electronic accumulators combined the functions of an adding machine and storage unit. No central memory unit existed, and storage was localized within the circuitry of the computer.

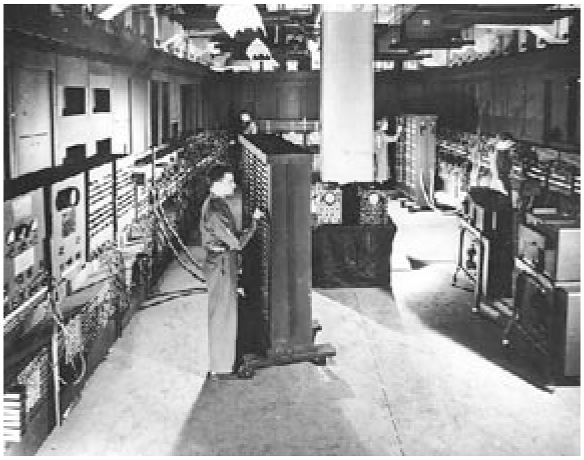


*Image: Popular Science, Apr. 1946 Page 84*

The primary aim of the designers was to achieve speed by making ENIAC as all-electronic as possible. The only mechanical elements in the final product were actually external to the calculator itself. These were an IBM card reader for input, a card punch for output, and the 1,500 associated relays.

An interesting side note occurred after the delivery of the prototype to the military, when Eckert and Mauchly formed a company to commercialize the computer. Disputes arose over who owned the patents for the design, and the professors were forced to resign from the faculty of the University of Pennsylvania. The concept of "technology transfer" from the university research labs to the private sector, which is common today, had no counterpart in the late 1940s and even into the 1980s.

The revolution in electronics can be traced to the tube's successful replacement with the discovery of the transistor[1] in 1947 by a team at Bell Labs (Shockley, Bardeen and Brattain). Based on the semiconductor technology, the transistor, like the vacuum tube, functioned as a switch or an amplifier. Unlike the tube, the transistor was small, had a very stable temperature, was fast and very reliable. Because of it's size and low heat, it could be arranged in large numbers in a small area, allowing the devices built from it to decrease significantly in size.

The transistor still had to be soldered into the circuits by hand, so the size was still limited. The ubiquitous presence of the transistor resulted in all sorts of mid-sized devices, from radios to computers that were introduced in the 1950s.

> The ENIAC patents (which covered basic patents relating to the design of electronic digital computers) were filed in 1947 by John W. Mauchly and J. Presper Eckert arising from the work conducted at the Moore School of Electrical Engineering at the University of Pennsylvania. In 1946, Eckert and Mauchly left the Moore School and formed their own commercial computer enterprise, the Electronic Control Company, which was later incorporated as the Eckert-Mauchly Computer Corporation. In 1950 Remington Rand acquired Eckert-Mauchly and the rights to the ENIAC patent eventually passed to Sperry Rand as a result of a merger of the Sperry Corporation and Remington Rand in 1955. After the patent was granted to the Sperry Rand Corporation in 1964, the corporation demanded royalties from all major participants in the computer industry. Honeywell refused to cooperate, so Sperry Rand then filed a patent infringement suit against Honeywell in 1967. Honeywell responded in the same year with an antitrust suit charging that the Sperry Rand-IBM cross-licensing agreement was a conspiracy to monopolize the computer industry, and also that the ENIAC patent was fraudulently procured and invalid.
>
> Ref: Charles Babbage Institute, Honeywell vs. Sperry Litigation Records, 1947-1972; Also see a first-person accounting by Charles McTiernan in an Anecdote article in the Annals of the History of Computing

The next breakthrough which was credited with spawning an entire industry of miniature electronics came in 1958 with the discovery (independently by two individuals) of the **integrated circuit**. The integrated circuit (IC, or Chip), invented by Jack St. Clair Kilby of Texas Instruments (later winner of the Nobel Prize in physics and one of the designers of the TI hand-held calculator) and Robert Noyce of Fairchild Electronics (later one of the founders of Intel), allowed the entire circuit (transistors, capacitors, resistors, wires, …) to be made out of silicon on a single board.

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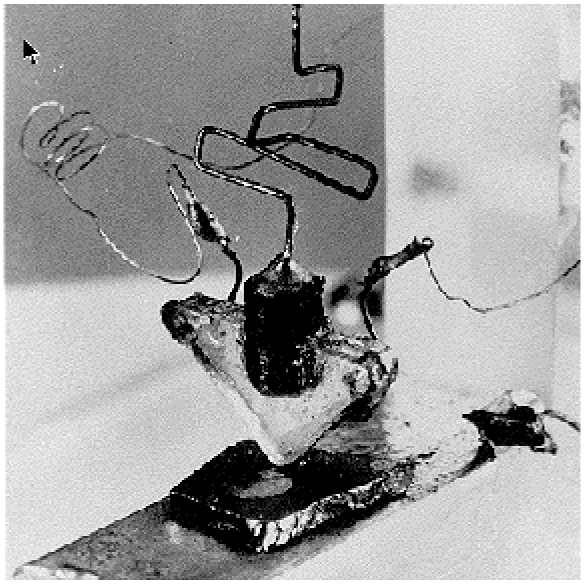
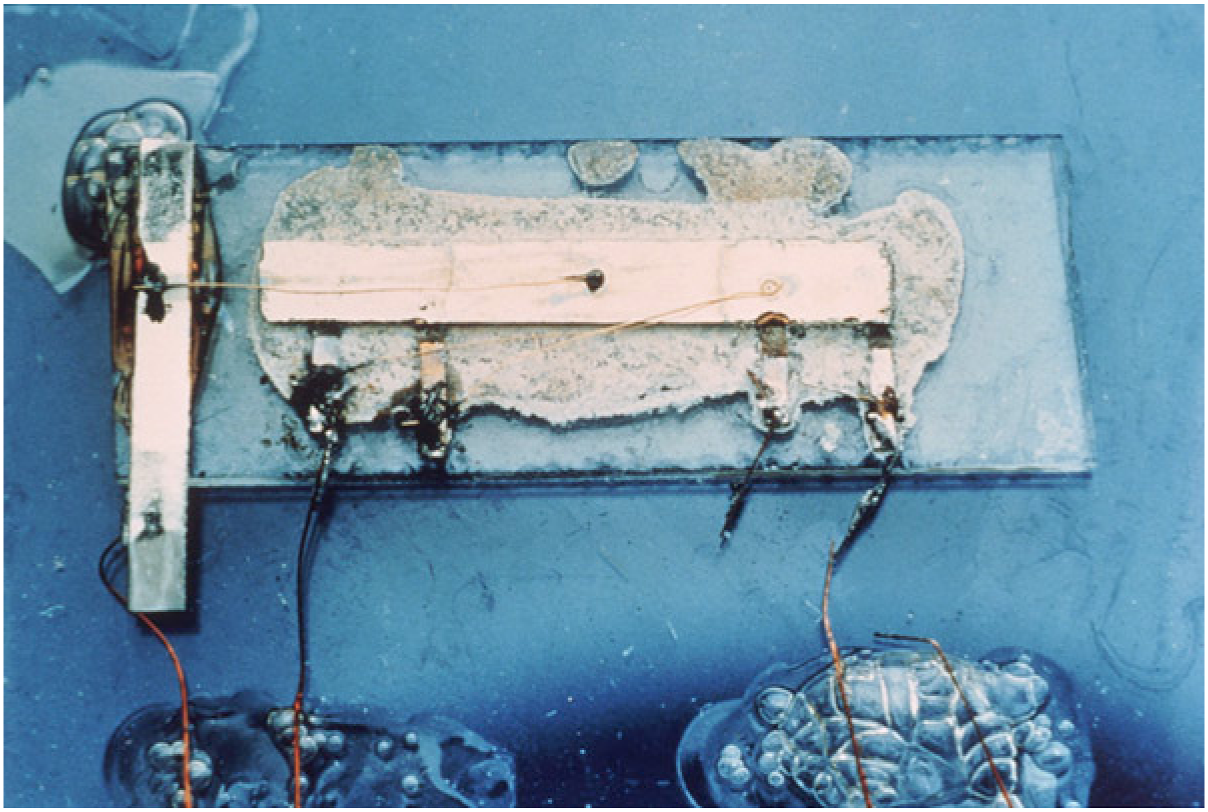
[1] Reference: http://www.porticus.org/bell/belllabs_transistor.html



*The earliest transistor (source: AT&T Bell Labs)*

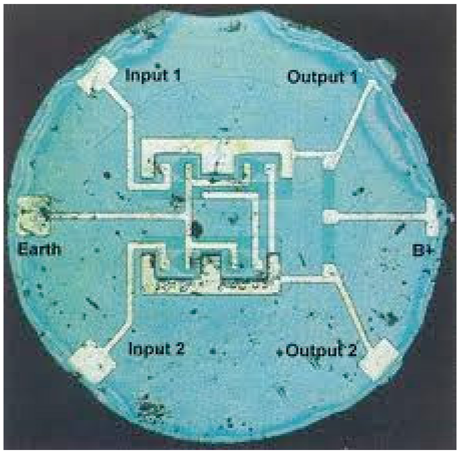
In the design of a circuit, connections must be of primary importance, so that the electrical current can traverse the entire circuit. In early circuit construction, several problems contributed to failure. First, manual assembly of huge numbers of tiny components resulted in many faulty connections. The second problem was one of size: if the components are too large or connections too long, electric signals can't travel fast enough through the circuit.

In 1958 Kilby came up with his solution to the miniaturization problem: make all the components and the chip out of the same block (monolith) of semiconductor material. Making all the parts out of the same block of material and adding the metal needed to connect them as a layer on top of it eliminated the need for individual discrete components. Circuits could be made smaller and the manual assembly part of the manufacturing process could be eliminated.



*Kilby "monolithic" integrated circuit (source: Texas Instruments)*

Noyce's solution, introduced six months later, solved several problems that Kilby's circuit had, mainly the problem of connecting all the components on the monolith. His solution was to add the metal as a final layer, and then remove enough to provide the desired flow of electrons; thus the "wires" needed to connect the components were formed. This made the integrated circuit more suitable for mass production.



*Noyce "unitary" IC (source: Fairchild Semiconductor)*

http://www.nobel.se/physics/educational/integrated_circuit/history/

http://www.computer-museum.org/collection/ti-icphoto.html
http://www.chiphistory.org/fairchild_ic.htm

The Encyclopedia of Computer Science identifies the Atanasoff–Berry Computer (ABC) as the first electronic digital computing device. Conceived in 1937, the machine was not programmable, being designed only to solve systems of linear equations. It was successfully tested in 1942. It was the first computing machine to use electricity, vacuum tubes, binary numbers and capacitors. The capacitors were in a rotating drum that held the electrical charge for the memory.

However, its intermediate result storage mechanism, a paper card writer/reader, was unreliable, and when inventor John Vincent Atanasoff left Iowa State College for World War II assignments, work on the machine was discontinued. The ABC pioneered important elements of modern computing, including binary arithmetic and electronic switching elements, but its special-purpose nature and lack of a changeable, stored program distinguish it from modern computers. The computer was designated an IEEE Milestone in 1990.

Atanasoff and Clifford Berry's computer work was not widely known until it was rediscovered in the 1960s, amidst conflicting claims about the first instance of an electronic computer. At that time, the ENIAC was considered to be the first computer in the modern sense, but in 1973 a U.S. District Court invalidated the ENIAC patent and concluded that the ENIAC inventors had derived the subject matter of the electronic digital computer from Atanasoff. The judge stated "Eckert and Mauchly did not themselves first invent the automatic electronic digital computer, but instead derived that subject matter from one Dr. John Vincent Atanasoff."

# Chapter 2: The emergence of graphics technology

# The emergence of graphics technology

The late 1940s and early 1950s saw rapid developments in hardware and software, and an emerging interest on the part of the federal government in visual representation. The computer graphics discipline was born.

*3D Reconstruction of Moon-rise Over Newark Earthworks, http://indianmounds.wordpress.com (2010)*

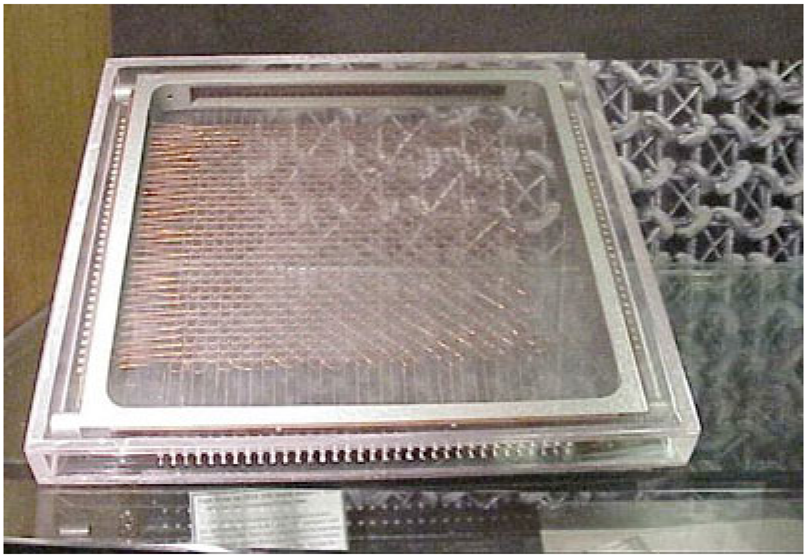
# 2.1 Whirlwind and SAGE

The evolution of the digital computer continued with the **Whirlwind** computer. Development of the Whirlwind began in 1945 under the leadership of Jay Forrester at MIT, as part of the Navy's Airplane Stability and Control Analyzer (ASCA) project. The system was proposed in order to provide a "programmable" flight simulation environment and was first demonstrated in 1951. This was not the first digital computer, but it was the first computer capable of displaying real time text and graphics, using a large oscilloscope screen.

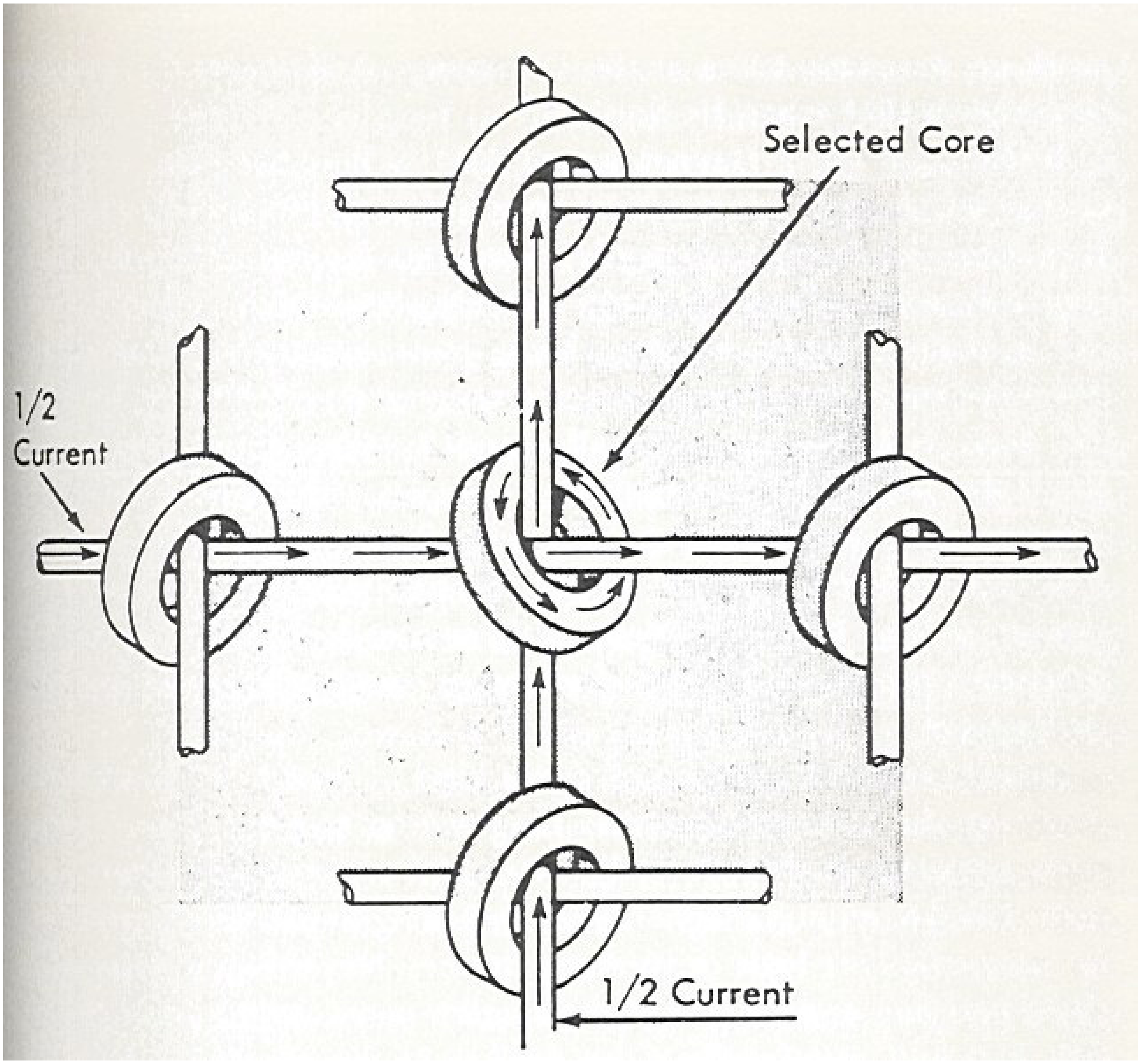
*Pictures used with the permission of The MITRE Corporation. ?Copyright – The MITRE Corporation. All Rights Reserved.*

Whirlwind received positional data related to an aircraft from a radar station in Massachusetts. The Whirlwind programmers had created a series of data points, displayed on the screen, that represented the eastern coast of Massachusetts, and when data was received from radar, a symbol representing the aircraft was superimposed over the geographic drawing on the screen of a CRT. Robert Everett (who later became CEO of Mitre Corporation) designed an input device, which was called a light gun or light pen, to give the operators a way of requesting identification information about the aircraft. When the light gun was pointed at the symbol for the plane on the screen, an event was sent to Whirlwind, which then sent text about the plane's identification, speed and direction to also be displayed on the screen.

As a result of performance and expense, Forrester opted not to use new mercury delay line memory or electrostatic storage tubes. Instead he investigated a magnetic ceramic called Deltamax, which could be subjected to magnetic pulses which would result in a change of state that could remain indefinitely. Called **core memory**, each component was a donut shaped metal that had two electrical wires strung through it. Neither was strong enough in power to change the state of the magnetism, but together they were. Thus it was a randomly addressable storage and access medium.



*A core memory component out of the Whirlwind computer. This bank has 32×32 bits and is approximately 14 inches square. Source: Mitre Corporation*

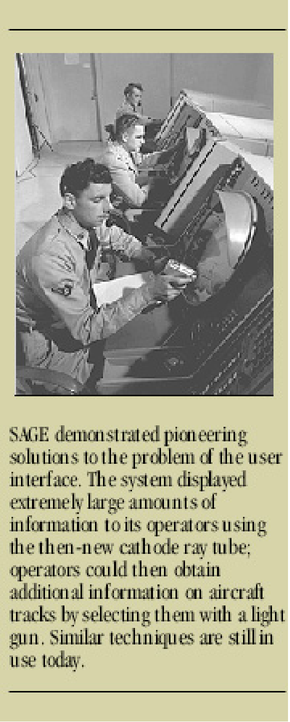


*How core memory works*

The Whirlwind project was very expensive and made up the bulk of the Office of Naval Research budget. As a result, it became the target of congressional budget cutters, who threatened to reduce the allocation from $1.15M to $0.25M in 1951. Through intense lobbying by MIT, the Whirlwind computer was ultimately adopted by the U.S. Air Force for use in its new **SAGE** (Semi-Automatic Ground Environment) air defense system, which became operational in 1958 with more advanced display capabilities.
http://www.mitre.org/about/sage.html

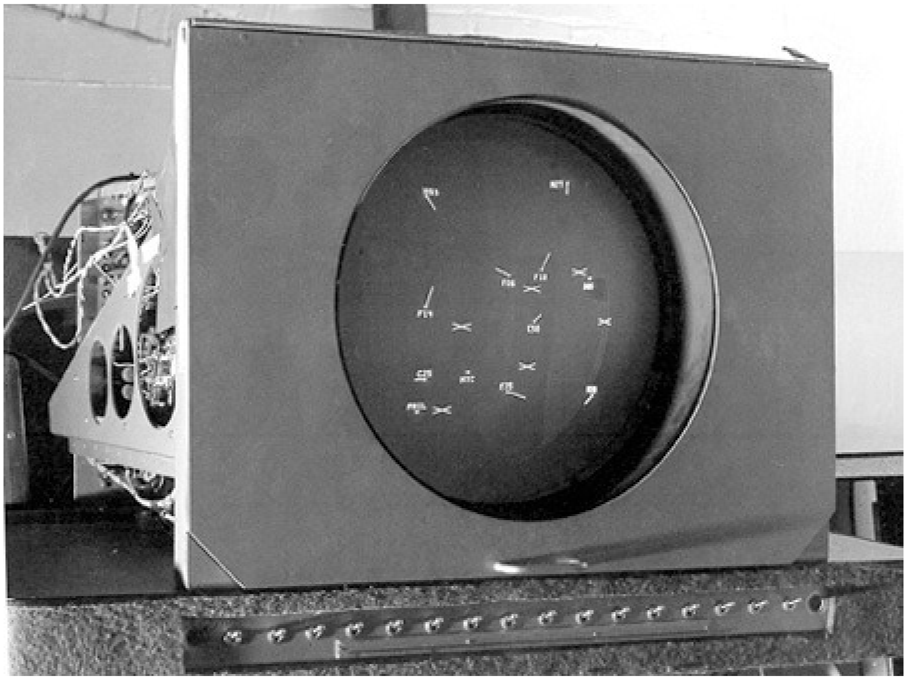
*The Whirlwind computer at MIT (circa 1951). In this photo, Stephen Dodd, Jay Forrester, Robert Everett, and Ramona Ferenz (seated at the CRT display) convene at the Whirlwind I test control in the Barta Building at MIT. Source: Mitre Corporation*

The Deltamax core was replaced by faster ferrite core memory in 1953. RCA applied for the contract to manufacture SAGE but it ultimately was awarded to IBM, who placed two Whirlwind computers in each of the 23 Air Force SAGE centers. Due to the launch of Sputnik, the Air Force became less concerned about long range bombers, and more concerned about intercontinental ballistic missiles, and it was phased out. The last of the Whirlwind-based SAGE computers was shut down in 1983, giving the Whirlwind a record for practical operational longevity among early digital computers.



SAGE demonstrated pioneering solutions to the problem of the user interface. The system displayed extremely large amounts of information to its operators using the then-new cathode ray tube; operators could then obtain additional information on aircraft tracks by selecting them with a light gun. Similar techniques are still in use today.

*SAGE*



*Vector display with geographical reference marks. A Whirlwind I computer generates and displays aircraft positions and auxiliary information on the console. (The direction and length of the vector indicate the aircraft's direction and speed.) The operator uses a row of switches below the scope face to choose the information (e.g., vectors, identification, and track numbers) to be displayed. In this photo, geographical reference information has been superimposed on the display in response to a switch control*

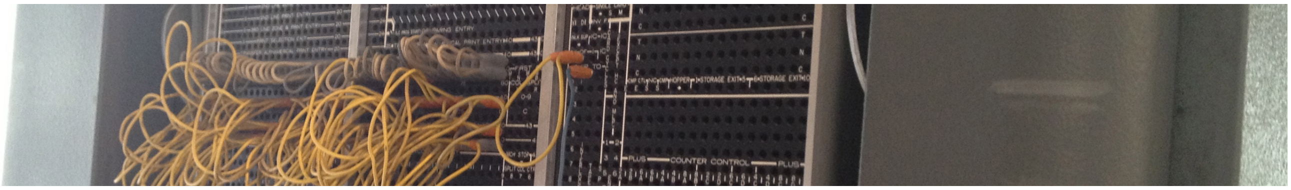
Besides the innovations related to computing hardware and software technology, the Whirlwind and SAGE projects helped to open the door to the computer graphics discipline by providing the CRT as a viable display and interaction interface, and introduced the light pen as an important input device. The Whirlwind and SAGE projects are documented in a 1999 book published by the National Academies Press, titled *Funding a Revolution: Government Support for Computing Research* (details are on page 91ff in Chapter 6). It can be read and/or downloaded at https://www.nap.edu/read/6323/chapter/1

**Movie 2.1** On Guard! (1956)

*http://www.youtube.com/watch?v=Kpahs3MAEDc*
*The first half of the movie "On Guard!" produced by IBM, is about the SAGE project. The second half covers the process of making computers flight-worthy.*

MIT licensed the technology for core memories to several computer companies – IBM, Univac, RCA, General Electric, Burroughs, NCR, Lockheed, and Digital Equipment Corporation, and memory suppliers, including Ampex, Fabri-TEk, Electronic Memory & Magnetics, Data Products, General Ceramics, and Ferroxcube. (National Academy Press)

# 2.2 Programming and Artistry



Although the hardware developments of the 1950s were extremely important to the CG discipline, there were also many innovations with respect to software that have allowed us to move rapidly forward to where we are today. For example, in the early development of the **ENIAC**, it was determined that the value of a digital computer was that you could “program” it to accomplish tasks, and then reprogram it to do something completely different.

*Grace Hopper*

**Grace Hopper** was a programmer on the Harvard Mark I and Mark II projects, and was hired by the Eckert and Mauchly Computer Company in 1949 to program the commercial version of the ENIAC. She experimented with the concept of software reusability, and published a paper in 1952 which laid out the general concepts of language translation and compilers. General computer languages were thus enabled, which created an environment that encouraged a significantly larger universe of computer users and applications. Hopper became a Commodore in the U.S. Navy in 1983 (a rank that was converted to an Rear Admiral – Lower Half in 1985), and died in 1992.[1]

http://www.cs.yale.edu/homes/tap/Files/hopper-story.html

In 1954 John Backus of IBM proposed the FORTRAN programming language, which was built around the idea that you could express numerical formulae in the programming language and the compiler could convert it to the base level instructions of the machine on which it resided.

In 1960 John McCarthy of MIT published a landmark paper in the Communications of the ACM on recursive functions in programming, in which he introduced a new programming language called LISP (for “List Processing”). The language contained a handful of simple operators and a functional notation, all built around

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1. On November 22, 2016, Grace Hopper was posthumously awarded the Presidential Medal of Freedom by President Barack Obama.

a central simple data structure called a *list* for both code and data. (LISP is the language used in the Symbolics graphics computer described in more detail in Section 6.3).

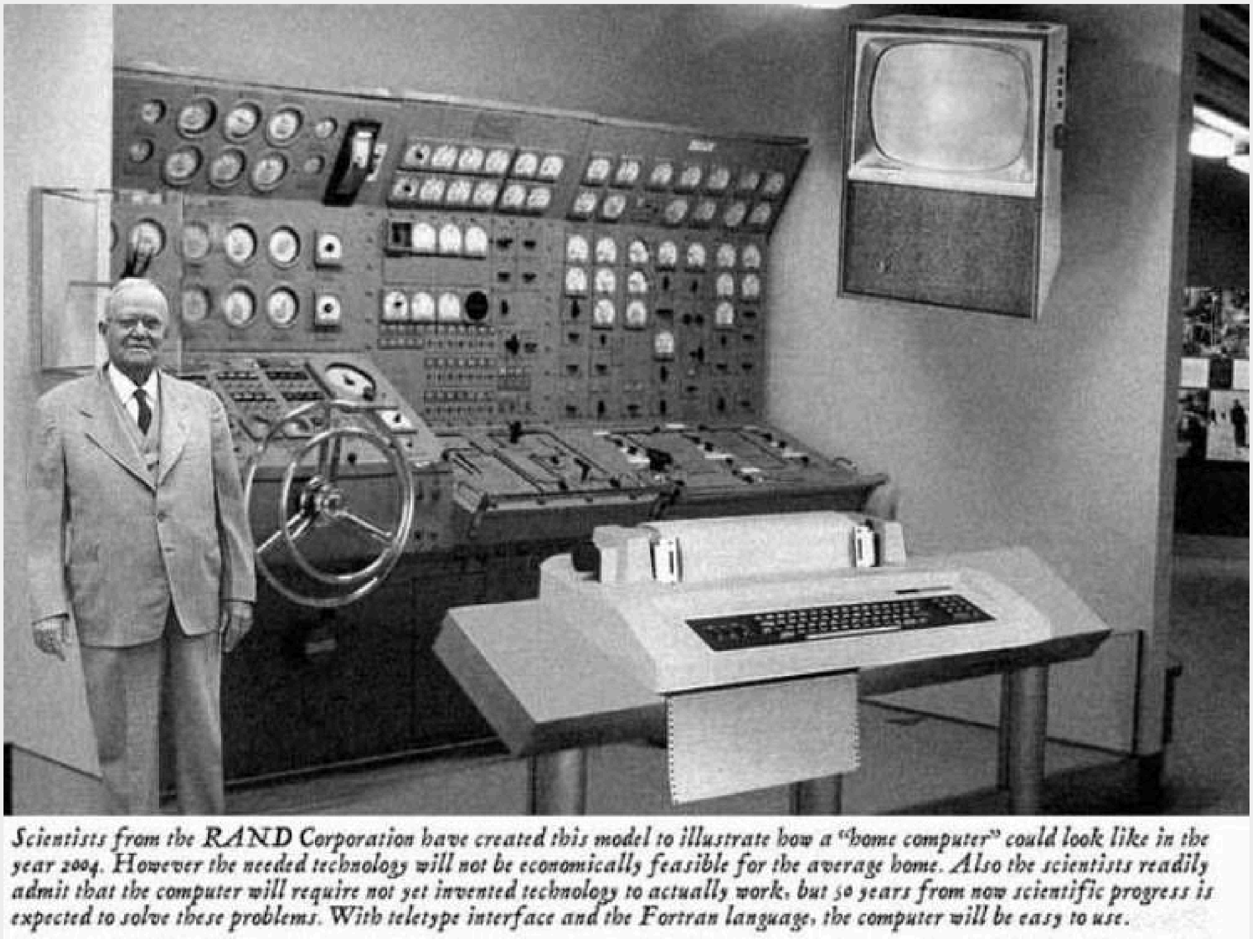
John G. Kemeny and Thomas E. Kurtz invented the language BASIC in 1964 for use at Dartmouth College. This language had a widespread influence on the development of the industry, as they made it freely available to everyone who wanted to learn how to program computers. Many other languages have evolved and been used by programmers in the intervening years.

Hopper, Grace. *The Education of a Computer*. Proceedings of the Association for Computing Machinery Conference (Pittsburgh) May 1952.

John McCarthy: *Recursive Functions of Symbolic Expressions and Their Computation by Machine, Part I*. Communications of the ACM 3(4): 184-195 (1960)    *[Note: Part 2 was never published]*

John G. Kemeny and Thomas E. Kurtz. *A Manual for BASIC, the elementary algebraic language designed for use with the Dartmouth Time Sharing System*. Dartmouth College Computation Center. 1964.

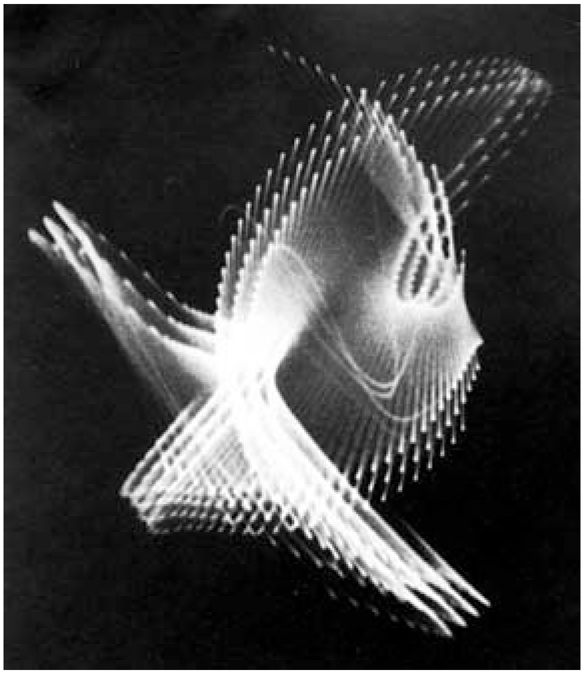
John Backus. *The History of FORTRAN I, II, and III*. History of Programming Languages, Association for Computing Machinery, 1981.



Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use.

This photo from the 1954 Modern Mechanics magazine predicted what the home computer might look like 50 years from then. The caption reads *"Scientists from the RAND Corporation have created this* *model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also, the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use."*

The aforementioned "larger universe of computer users" that took advantage of Hopper's early programming innovations included artists and designers, as well as mathematicians and computer engineers. Sometimes the difference between the diverse groups was blurry at best. In the early days of interacting with the new digital computer, often investigations into issues such as complex math formulas or ergonomic design resulted in visual images produced on the computer that have remained in our discipline as contributions to the field of art.

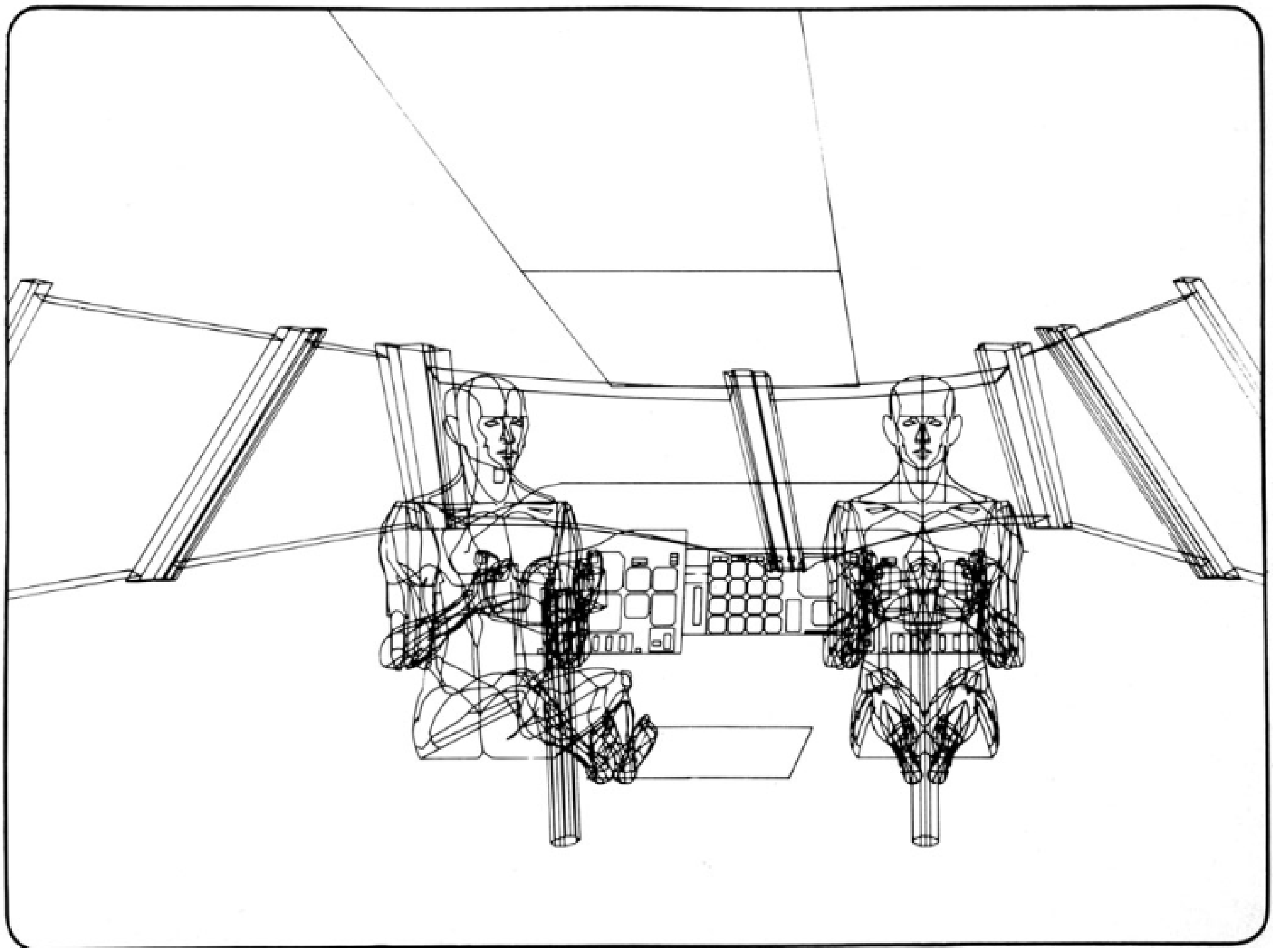


*Laposky's Oscillon #4 (source: Electronic Abstractions -Sanford Museum).*

For example, **Ben Laposky** was a mathematician and artist from Iowa. In 1950, he created the first graphic images generated by an electronic (in his case, an analog) machine. His electronic oscilloscope imagery was produced by manipulated electronic beams displayed across the fluorescent face of an oscilloscope's cathode-ray tube and then recorded onto high-speed film. He called his oscillographic artworks 'oscillons' and 'electronic abstractions'. The mathematical curves that were created by this method were similar to the Lissajous mathematical wave form. (Another artist working with the same approach was Herbert Franke from Germany. More about Franke can be read in Chapter 9 of this book.)

More about Laposky can be found at http://digitalartmuseum.org/laposky/index.htm

To learn more about Lissajous patterns, go to? http://www.math.com/students/wonders/lissajous/lissajous.html

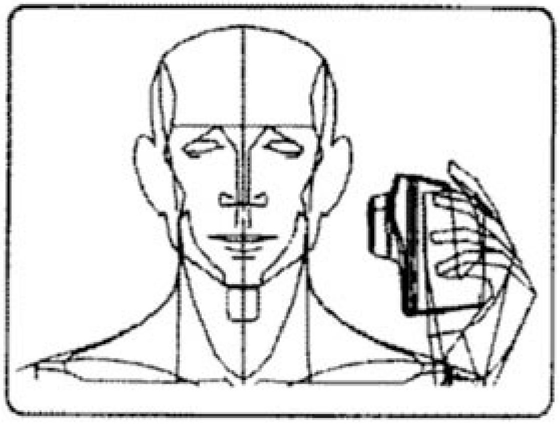


*“First Man” – 1968 – (source: Proceedings SPIE 166, 1978)*

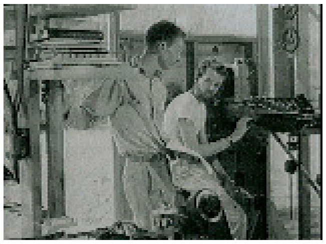
**William Fetter** was a graphic designer for Boeing Aircraft Co. and in 1960, was credited with coining the phrase “Computer Graphics” to describe what he was doing at Boeing at the time. (Fetter has said that the terms were actually given to him by Verne Hudson of the Wichita Division of Boeing.)

As Fetter stated in a 1978 interview, “There has been a long-standing need in certain computer graphics applications for human figure simulations, that as descriptions of the human body are both accurate and at the same time adaptable to different user environments.” His early work at Boeing was focused on the development of such ergonomic descriptions. One of the most memorable and iconic images of the early history of computer graphics was such a human figure, often referred to as the “Boeing Man”, but referred to by Fetter as the “First Man”.
(Source: http://courses.washington.edu/eatreun)

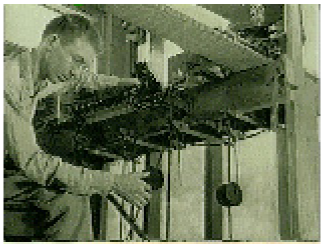
In 1970, Fetter left Seattle to work in Los Angeles, where he created one of the first in-perspective computer graphics TV commercials, a commercial for Norelco. He then moved to Carbondale, Illinois to become the Southern Illinois University Design Department Chairman, working with Buckminster Fuller. Fetter died in 2002.



*"Norelco Commercial" – 1970 (source: Proceedings SPIE 166, 1978)*



*John and James Whitney*



*John Whitney*

**John Whitney, Sr.** was one of the earliest and most influential of the computer animation pioneers. He came at the problem from the background of film, working with his brother James Whitney[2] on a series of experimental films in the 1940s and 1950s.

His work in this area gave him the opportunity to collaborate with well known Hollywood filmmakers, including Saul Bass.

His earliest computer work used analog devices for controlling images and cameras. After the second world war, Whitney purchased surplus military equipment and modified it to be used in his art making. One such device was an analog mechanism used in military anti-aircraft controllers, the M-5 (and later the M-7). Whitney and his brother converted this device of war into an animation controller, and used it together with a mounted camera as an animation stand.

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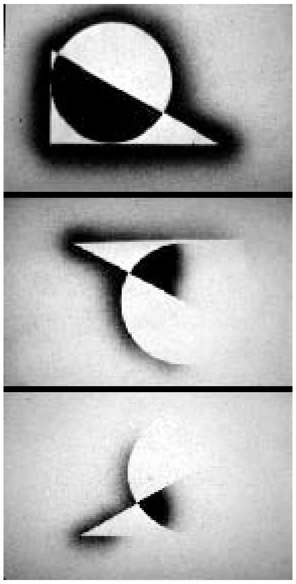
[2] John Whitney's younger brother James was famous in his own right, for work in the traditional animation filmmaking field. William Moritz wrote an interesting article about the younger Whitney (with corrections by the Center for Visual Music) called *Who's Who in Filmmaking: James Whitney* in Sightlines, Vol.19, no.2, Winter 1985/1986.

*Left: John Whitney Sr. filming from the screen;?Next page: scenes from his animation Spirals, and John Whitney. (Source: Animation World Magazine)*

His son John Jr. said the following about his dad's approach:

> I don't know how many simultaneous motions can be happening at once. There must be at least five ways just to operate the shutter. The input shaft on the camera rotates at 180 rpm, which results in a photographing speed of 8 frame/s. That cycle time is constant, not variable, but we never shoot that fast. It takes about nine seconds to make one revolution. During this nine-second cycle the tables are spinning on their own axes while simultaneously revolving around another axis while moving horizontally across the range of the camera, which may itself be turning or zooming up and down. During this operation we can have the shutter open all the time, or just at the end for a second or two, or at the beginning, or for half of the time if we want to do slit-scanning. [3]

Unlike the digital computer which requires the processing of mathematical equations as its input, Whitney's analogue computer had to have its information ready before it was processed, meaning that a template had to be created. The "information" or image source was hi-con **Kodalith** film negatives. When manipulated by the cam machine in a precise orbital motion, with an added movement differential, the result was animation. His insight was to harness the cam and ball integrators (formerly used as dedicated equation solvers for the gun fuse timing) as a source of differential motion.



*Scenes from Variations*

http://www.siggraph.org/artdesign/profile/whitney/home.html

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[3] Youngblood, Gene. Expanded Cinema (New York. E.P. Dutton & Company, 1970 (page 210)

After establishing his company Motion Graphics, Inc in 1960, he used his analog devices for the opening to the Hitchcock movie Vertigo in 1961. His company was focused on producing titles for film and television, and was also used in graphics for commercials. But Whitney was far more interested in the use of the technology as an art form, and began a series of collaborations in art making that lasted for years.

Many of these early collaborations revolved around the advancement of the vector graphics device as a viable tool for making art. Whitney received funding from IBM to take a look at the use of IBM equipment in the design of motion. He worked with IBM programmers in the development of a language for extending the computer to the control of graphics devices. This resulted in one of his most famous animations, Permutations, in 1968. Whitney went on to a residency at MIT in the Center for Advanced Visual Studies. Later he utilized the equipment of his son John, Jr., at his commercial company Information International Inc. (III) and created his Matrix III animation; he joined with artist/programmer Larry Cuba with funding from the National Endowment for the Arts and the Judith S. Thomas Foundation to produce what is arguably his second most famous work, Arabesque. In this film, Whitney demonstrated the concepts of "harmonic progression" through the vehicle of Islamic architecture.

*John Whitney*

Whitney joined the faculty at UCLA and supervised the work of a large number of animation students. Their collaboration, Digital Harmony (also the name of a book he wrote) was included in the 1984 SIGGRAPH electronic theatre and reflected one of his primary philosophies, that harmony not only exists in music, but in visual imagery and life in general. Whitney passed away in 1995.

*Source of images: Animation World Magazine article by William Moritz on John Whitney, 1997*

**Movie 2.2** – John Whitney Animation Flipbook
http://www.youtube.com/watch?v=_cmrTxtlgLA?

**Movie 2.3** – Excerpt from "Computers: Challenging Man's Supremacy" (1976)

https://www.youtube.com/watch?v=5eMSPtm6u5Y

**Movie 2.4** – Interview from "The Screening Room" WCVB-5 Boston

https://www.youtube.com/watch?v=BaW4DTKNflA

**Movie 2.5** – Interview with John Whitney before his death

https://www.youtube.com/watch?v=pGH5aCYtjeE

**Movie 2.6** – Catalog (1961)

https://www.youtube.com/watch?v=TbV7loKp69s

**Movie 2.7** – Arabesque (1975)

https://www.youtube.com/watch?v=sQrq7S0dP54

**Movie 2.8** – Lapis James Whitney 1966

http://www.youtube.com/watch?v=kzniaKxMr2g?

**Movie 2.9** – Permutations (1966)
http://www.youtube.com/watch?v=BzB31mD4NmA?

**Movie 2.10** – Matrix III (1972)
http://www.youtube.com/watch?v=ZrKgyY5aDvA

# 2.3 MIT's Lincoln Labs

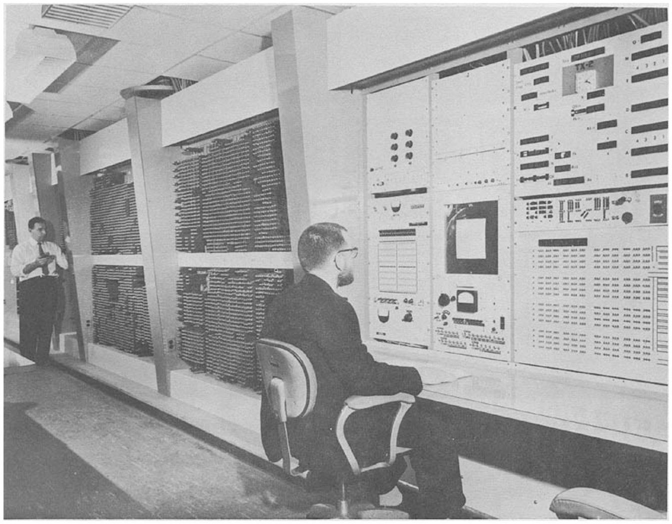
Continuing the development of the digital computer, the TX-2 (1959) computer at MIT's Lincoln Laboratory was key in the evolution of interactive computer graphics. The Air Force paid Lincoln Laboratory to build TX-0, and later TX-2 as demonstrations that transistors, themselves relatively new, could be the basis of major computing systems. (Digital Equipment Company (DEC) formed around the people that built these machines. DEC's PDP-1 and PDP-6 computers commercialized the TX-0 and TX-2 designs.)

*User at the console of the Digital Equipment Co. PDP-1 computer. (Source: Digital Equipment Corp.)*

TX-2 was a giant machine by the standards of the day, in part because it had 320 kilobytes of fast memory, about twice the capacity of the biggest commercial machines. It had magnetic tape storage, an on-line typewriter, the first Xerox printer, paper tape for program input, and most important for the graphics industry, a nine inch CRT. The display, a light pen, and a bank of switches were the interface on which the first interactive computer graphics system was based.

*Interacting with Sketchpad*

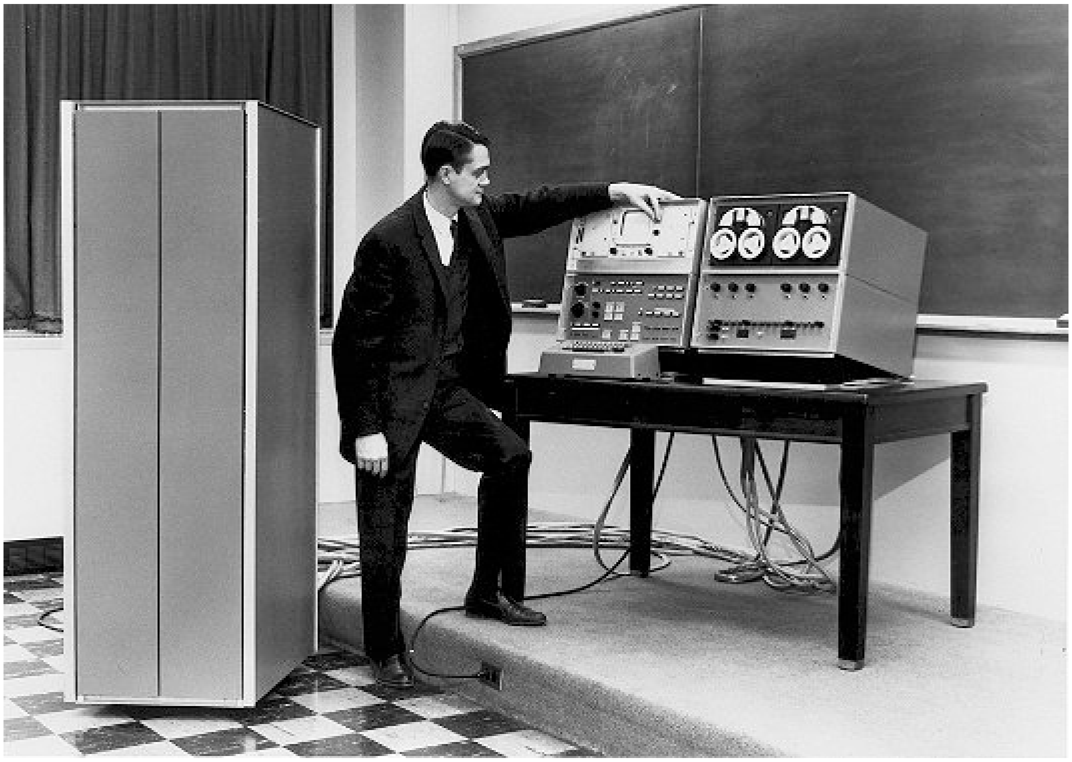
The purpose of the TX-2 was to investigate the use of Surface Barrier transistors for digital circuits. Prior to this computers were made with vacuum tubes, and it was thought that transistors would increase the reliability of these computers. Programs were written on paper tape, and fed into the TX-2 by the programmer. In the early sixties, few computers ran "on line." Instead, most computers ran "batches" of jobs submitted by users to the computer operators who scheduled the jobs to keep the computer fully occupied. Turn around time for each job was usually an hour or more, and often overnight.



*TX-2 Computer (Source: Ballistics Research Laboratory Report 1115, March 1961)*

Wes Clark, the man who designed the TX-2, integrated a number of man-machine interfaces that were just waiting for the right person to show up to use them in order to make a computer that was "on-line". His computer, the LINC, is considered the first minicomputer and a forerunner to the personal computer. Originally named the "Linc", suggesting the project's origins at the Lincoln Laboratory, it was renamed LINC after the project moved from the Lincoln Laboratory.

When selecting a PhD thesis topic, an MIT student named Ivan Sutherland (Chapter 3) looked at the simple cathode ray tube and light pen on the TX-2's console and thought one should be able to draw on the computer. Thus was born *Sketchpad*, and with it, interactive computer graphics.

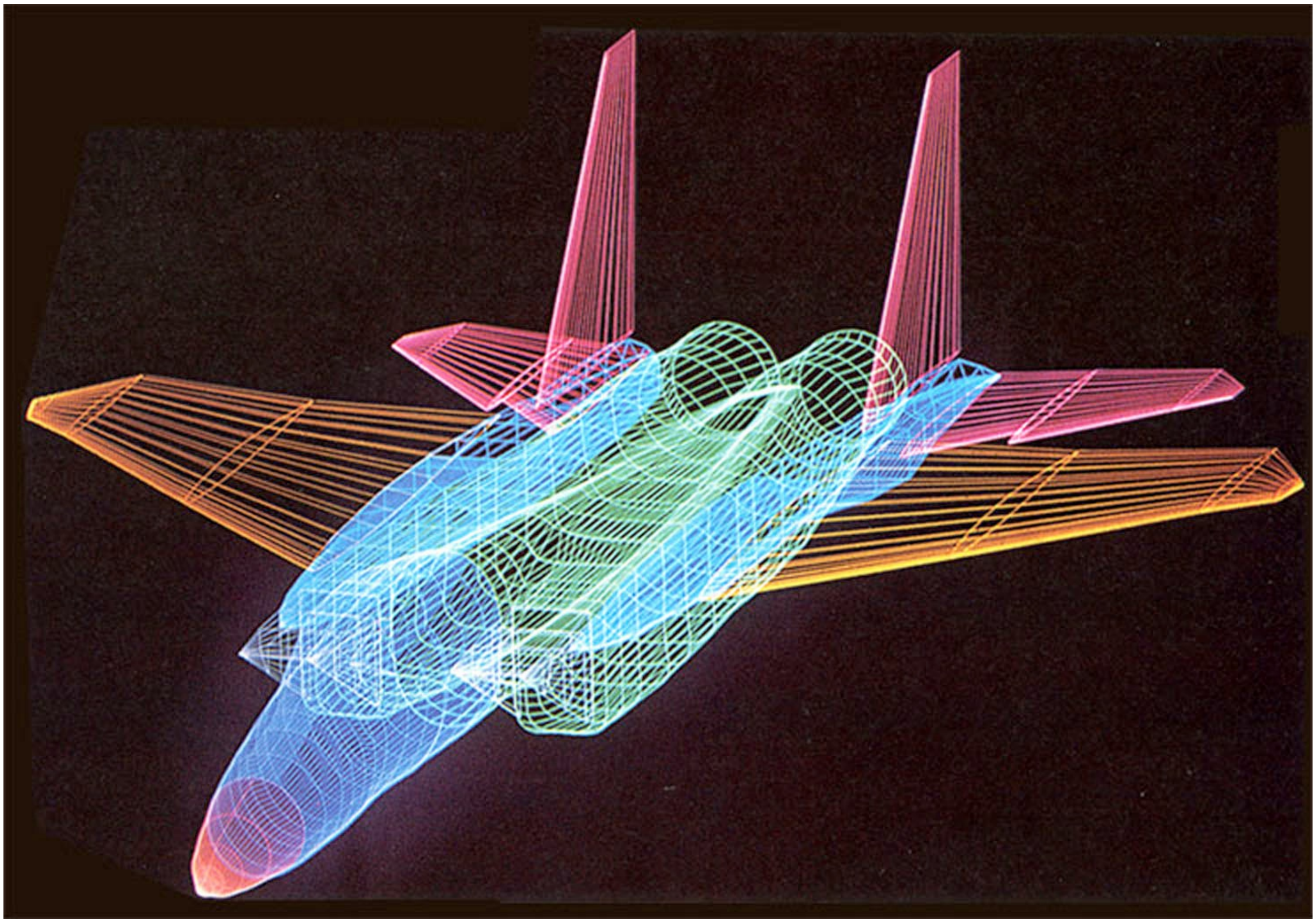


*Wes Clark with the LINC computer (Source: Computer History Museum) http://www.computerhistory.org/revolution/minicomputers/11/334*

# Chapter 3: The computer graphics industry evolves

# The computer graphics industry evolves

The early research and development efforts associated with the military and government sponsored invention and development of the computer, and the desire to visually represent data that was generated or stored on these computers, quickly led to the establishment of private sector companies and the beginning of the computer graphics industry.



*Aircraft design from screen of Evans and Sutherland graphics workstation*

# 3.1 Work continues at MIT

As mentioned in the previous chapter, activities at the Massachusetts Institute of Technology helped shape the early computer and computer graphics industries. Development at MIT took place in several different laboratories, including the Lincoln Labs, Electronics System Laboratory, the Center for Advanced Visual Studies, the Architecture Machine Group and the Media Lab. As mentioned in Chapter 1, Jay Forrester of the Servomechanisms Lab was chosen by Gordon Brown to develop the Whirlwind computer in the mid-40s. The Whirlwind and Forrester were moved to the Digital Computer Lab and started focusing on using the computer for graphics displays, for air traffic control and gunfire control, and became part of the government's SAGE (Semi-Automatic Ground Environment) program.

## Ivan Sutherland and Sketchpad

**Ivan Sutherland**, acknowledged by many to be the "grandfather" of interactive computer graphics and graphical user interfaces, worked on his PhD in Electrical Engineering in the Lincoln Labs on their TX-2 computer. Sutherland learned to program in high school using a small relay computer called SIMON[1].

---

[1] A 1950 fact sheet from Columbia University called SIMON "a very simple model, mechanical brain -- the smallest complete mechanical brain in existence." This fact sheet can be found at http://www.blinkenlights.com/classiccmp/berkeley/simonfaq.html

SIMON was a relay-based computer with six words of two bit memory. Its 12 bits of memory permitted SIMON to add up to 15. Sutherland's first big computer program was to make SIMON divide. To make division possible, he added a conditional stop to SIMON's instruction set. This program was a great accomplishment, it was the longest program ever written for SIMON, a total of eight pages of paper tape.

This was the beginning of a distinguished career in computers, graphics, and integrated circuit design. He earned his B.S. in Electrical Engineering at Carnegie Institute of Technology (now Carnegie Mellon University) on a full scholarship. He received an M.S. from Cal Tech, and then enrolled at MIT to work on his Ph.D. His dissertation centered around an interactive computer drawing program that he called Sketchpad, which was published in 1963. His contributions moved graphics from a military laboratory tool to the world of engineering and design. Sutherland made a movie of the interactive use of ***Sketchpad***, which became somewhat of a cult film. It is widely acknowledged that every major computer graphics research lab in the country had a copy of the film, and researchers and students still refer to it over and over, as it influenced their developmental work so significantly.

***Movie 3.1*** *Alan Kay discusses Sketchpad*
https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/alankay-on-sketchpad-1987.m4v

*Excerpted from a 1987 distinguished lecture series by computer interface pioneer Alan Kay, titled "Doing with Images Makes Symbols: Communicating with Computers"*

*Source: http://www.archive.org/details/AlanKeyD1987*

Sutherland's software, described in a 1963 paper, *Sketchpad: A Man-machine Graphical Communications System*, used the light pen to create engineering drawings directly on the CRT. Highly precise drawings could be created, manipulated, duplicated, and stored. The software provided a scale of 2000:1, offering large areas of drawing space. Sketchpad pioneered the concepts of graphical computing, including memory structures to store objects, rubber-banding of lines, the ability to zoom in and out on the display, and the ability to make perfect lines, corners, and joints. This was the first **GUI (Graphical User Interface)** long before the term was coined.

*Using Ivan Sutherland's Sketchpad on TX-2*

*The following text is from a citation for Dr. Sutherland when he won the Franklin Institute Certificate of Merit (1996):*

> *At a time when cathode ray tube monitors were themselves a novelty, Dr. Ivan Sutherland's 1963 software-hardware combination, Sketchpad, enabled users to draw points, line segments and circular arcs on a cathode ray tube with a light pen. In addition Sketchpad users could assign constraints to whatever they drew and specify relationships among the segments and arcs. The diameter of arcs could be specified, lines could be drawn horizontally or vertically, and figures could be built up from combinations of elements and shapes. Figures could be copied, moved, rotated, or resized and their constraints were preserved. Sketchpad also included the first window-drawing program and clipping algorithm which made possible the capability of zooming in on objects while preventing the display of parts of the object whose coordinates fall outside the window.*
>
> *The development of the Graphical User Interface, which is ubiquitous today, has revolutionized the world of computing, bringing to large numbers of discretionary uses the power and utility of the desk top computer. Several of the ideas first demonstrated in Sketchpad are now part of the computing environments used by millions in scientific research, in business applications, and for recreation. These ideas include:*
>
> 1. *the concept of the internal hierarchic structure of a computer-represented picture and*
> 2. *the definition of that picture in terms of sub-pictures;*
> 3. *the concept of a master picture and of picture instances which are transformed versions of the master;*
> 4. *the concept of the constraint as a method of specifying details of the geometry of the picture;*
> 5. *the ability to display and manipulate iconic representations of constraints;*
> 6. *the ability to copy as well as instance both pictures and constraints;*
> 7. *some elegant techniques for picture construction using a light pen;*
> 8. *the separation of the coordinate system in which a picture is defined from that on which it is displayed; and*
> 9. *recursive operations such as "move" and "delete" applied to hierarchically defined pictures.*

*The implications of some of these innovations (e.g., constraints) are still being explored by Computer Science researchers today.*

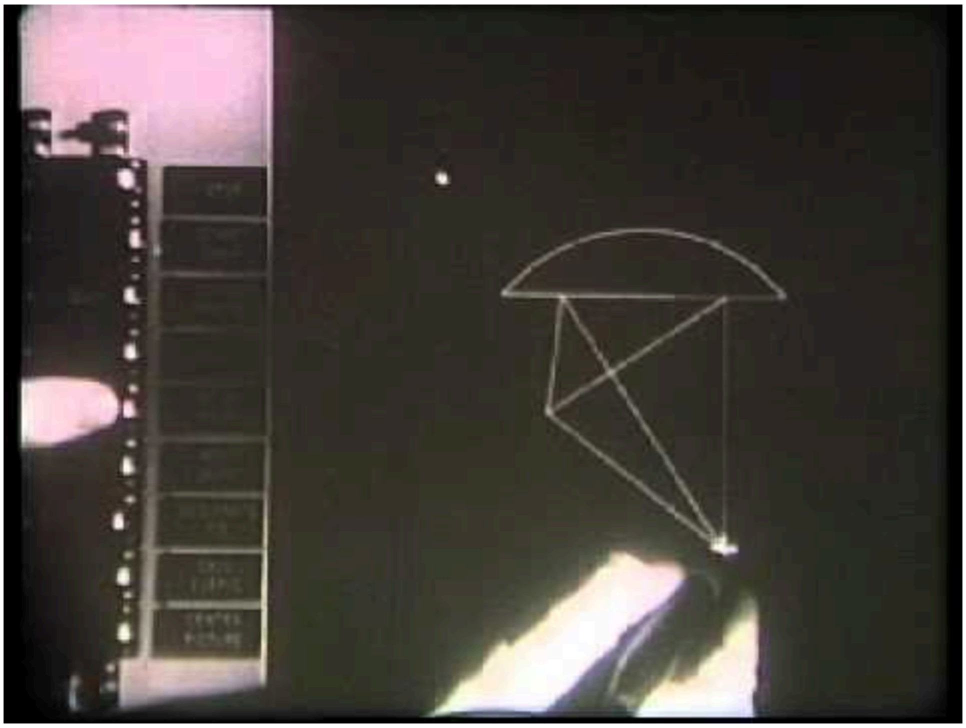
Sutherland, Ivan, *SKETCHPAD: A Man-Machine Graphical Communication System*, PhD dissertation, MIT, 1963. Reproduced as Technical Report Number 574, University of Cambridge Computer Laboratory, UCAM-CL-TR-574, ISSN 1476-2986,
*http://www.cl.cam.ac.uk/*

Sutherland, Ivan, *SKETCHPAD: A Man-Machine Graphical Communication System*, Proceedings of the AFIPS Spring Joint Computer Conference, Detroit, Michigan, May 21-23, 1963, pp. 329-346.
*http://www.guidebookgallery.org/articles/*

*Toward a Machine with Interactive Skills*, from *Understanding Computers: Computer Images*, Time-Life Books, 1986

*More on Ivan Sutherland can be found in the chapters and sections related to the University of Utah and Evans & Sutherland Computer Company (Chapters 4 and 13, respectively.)*

**Movie 3.2** Sketchpad



*https://www.youtube.com/watch?v=57wj8diYpgY*

*A copy of the first 6 1/2 minutes of the original Sketchpad demo, originally recorded on 16mm film*

## Center for Advanced Visual Studies

The Center for Advanced Visual Studies was established in 1967. Its founder, the artist and MIT professor Gyorgy Kepes, conceived of the Center as a fellowship program for artists.

The Center's initial mission was twofold:

- to facilitate "cooperative projects aimed at the creation of monumental scale environmental forms" and
- to support participating fellows in the development of "individual creative pursuits."

To achieve these goals, fellows worked collaboratively with each other and with the wider MIT community. Other fellows at CAVS extended this idea of artists working on projects with the assistance of engineers and scientists.

Kepes, who had taught at the New Bauhaus in Chicago prior to joining the faculty of MIT's School of Architecture and Planning in 1946, strongly believed in the social role of the artist. With the founding of the Center he sought to bring about the "absorption of the new technology as an artistic medium; the interaction of artists, scientists, engineers, and industry; the raising of the scale of work to the scale of the urban setting; media geared to all sensory modalities; incorporation of natural processes, such as cloud play, water flow, and the cyclical variations of light and weather; [and] acceptance of the participation of 'spectators' in such a way that art becomes a confluence."

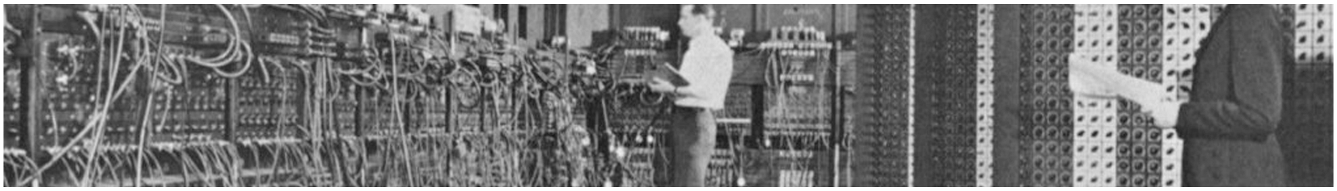
According to the MIT CAVS website,

> The CAVS was established by Professor Kepes, who emphasized the responsibilities of artists in building bridges between individuals and their environment, between individuals in groups, and between each of us and our inner lives.

## MIT Media Laboratory

The Media Laboratory was formed in 1980 by Nicholas Negroponte and Jerome Wiesner, growing out of the Architecture Machine Group, and building on the seminal work of faculty members such as Marvin Minsky in cognition, Seymour Papert in learning, Barry Vercoe in music, Muriel Cooper in graphic design, Andrew Lippman in video, and Stephen Benton in holography. The Media Lab conducted advanced research into a broad range of information technologies including digital television, holographic imaging, computer music, computer vision, electronic publishing, artificial intelligence, human/machine interface design, and education-related technologies. Its charter was to invent and creatively exploit new media for human well-being and individual satisfaction without regard to present-day constraints. They employed supercomputers and extraordinary input/output devices "to experiment today with notions that will be commonplace tomorrow." The not-so-hidden agenda was to drive technological inventions and break engineering deadlocks with new perspectives and demanding applications.
http://www.media.mit.edu/about/index.html

# 3.2 TX-2 and DEC

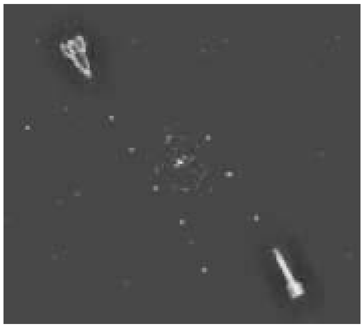


Another MIT engineer, **Ken Olsen**, was working at Lincoln Labs on the TX-2 project. In 1957 Olsen founded the Digital Equipment Corporation (DEC). He shepherded the transition of the TX-2 technology into a commercial environment, and in 1961 started construction of DEC's first computer, the PDP-1. The PDP-1 was considered a milestone in the computer era, because it was the world's first commercial interactive computer. It was used by its purchasers to pioneer timesharing systems, making it possible to have access to much more (affordable) computing power than ever before.

*DEC PDP-1*

In 1961 a young computer programmer from MIT, Steve Russell led a team that created the first computer game. It took the team about 200 man-hours to write the first version of ***Spacewar!*** (or *Spacewar*). They wrote *Spacewar* on a PDP-1 which was a donation to MIT from DEC, who hoped MIT's think tank would be able to do something remarkable with their product.

The PDP-1's **operating system** was the first to allow multiple users to share the computer simultaneously. This was perfect for playing *Spacewar*, which was a two-player game involving warring spaceships firing photon torpedoes. Each player could maneuver a spaceship and score by firing missiles at his opponent while avoiding the gravitational pull of the sun. Russell transferred to Stanford University, where he introduced computer game programming and *Spacewar* to an engineering student named Nolan Bushnell, who went on to write the first coin-operated computer arcade game and start Atari Computers.



*Screenshot from Spacewar!*

> "We had this brand new PDP-1," Steve Russell recalls. "It was the first minicomputer, ridiculously inexpensive for its time. And it was just sitting there. It had a console typewriter that worked right, which was rare, and a paper tape reader and a cathode ray tube display. Somebody had built some little pattern-generating programs which made interesting patterns like a kaleidoscope. Not a very good demonstration. Here was this display that could do all sorts of good things! So we started talking about it, figuring what would be interesting displays. We decided that probably you could make a two-dimensional maneuvering sort of thing, and decided that naturally the obvious thing to do was spaceships."
> *From SPACEWAR – Fanatic Life and Symbolic Death Among the Computer Bums, by Stewart Brand. Rolling Stone Magazine, 12/7/1972*

Through the 1960s DEC produced a series of machines aimed at a price/performance point below IBM 's 18-bit word, core memory mainframe machines. In 1964 they introduced the PDP-8. It was a smaller 12-bit word machine that sold for about $16,000. The PDP-8 is generally regarded as the first minicomputer. It was important historically because their low cost and portability made it the first computer that could be purchased by end users as an alternative to using a larger system in a data center. Many small computer graphics labs could now have a dedicated computer on which to experiment with new software and hardware.

*DEC PDP-9*

Arguably the most important computer in the PDP series was the PDP-11, which switched to a 16-bit word once everyone in the computer industry started using ASCII. PDP-11 machines were introduced in the market essentially as upscale PDP-8s, but as improvements to integrated circuits continued, they eventually were packaged in cases no larger than a modern PC . Their larger PDP-10 cousins, which used a 36-bit architecture, were aimed at data-processing centers instead, eventually being sold as the DECsystem10 (or PDP-10) and DECsystem20.

While the PDP-11 systems supported several operating systems, including DEC's RSTS system, their most important role was to run Bell Labs' new UNIX operating system that was being made available to educational institutions.

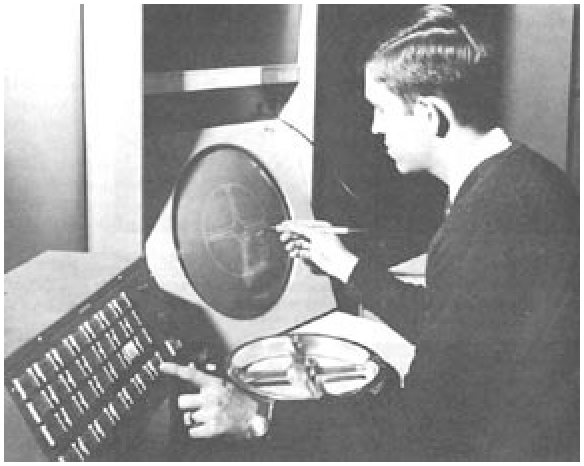
DEC PDP-11/45

The PDP-11 had a 64K address space. Most models had a **paged architecture** and memory protection features to allow timesharing, and could support split I&D architectures for an effective address size of 128K.
http://www.wikipedia.org/wiki/PDP-11

In 1976 DEC decided to move to an entirely new 32-bit platform, which they referred to as the super-mini. They released this as the VAX 11/780 in 1978, and immediately took over the vast majority of the minicomputer market. Desperate attempts by competitors such as Data General (which had been formed in 1968 by a former DEC engineer who had worked on a 16-bit design that DEC had rejected) to win back market share failed, due not only to DEC's successes, but the emergence of the microcomputer and workstation into the lower-end of the minicomputer market. In 1983 , DEC cancelled their "Jupiter" project, which had been intended to build a successor to the PDP-10, and instead focused on promoting the VAX as their flagship model.

The VAX series had an instruction set that is rich even by today's standards. In addition to the paging and memory protection features of the PDP series, the VAX supported **virtual memory**.
http://williambader.com/museum/vax/vaxhistory.html

DEC was also an important contributor to the graphics display and terminal market. Their products were influenced by work in the Electronic Systems Laboratory (ESL) at MIT. In 1968 they introduced the DEC 338 intelligent graphics terminal, which was a refresh display with point, vector and character drawing capability. Other devices in this class were the DEC 340, IBM 2250, and IMLAC PDS-1. In 1974 they marketed the VT-52, which incorporated the first addressable cursor in a graphics display terminal. One of their most functional terminals, the VT-100 was introduced in 1981, and operated in hundreds of computer rooms around the world.



DEC 340 display

*DEC VT-52*

*DEC VT-100*

A common object in graphics labs was the disk cartridge, such as the DEC RK05 and RL02. The RK05 had 1.25 MB, and the RL02 had approximately 2.2 MB of storage (1.1 on each side) and a 60 ms seek time.

*DEC RL-02*

*The PDP-11 was an important contributor to the graphics industry development, as it was one of the more common computers in universities and research labs, and DEC made RSTS and Unix available to educational institutions at little or no cost. The woman in the above documentation cover is loading the PDP-11 disk cassette, and the woman below is loading the punch card reader.*

Interesting notes:

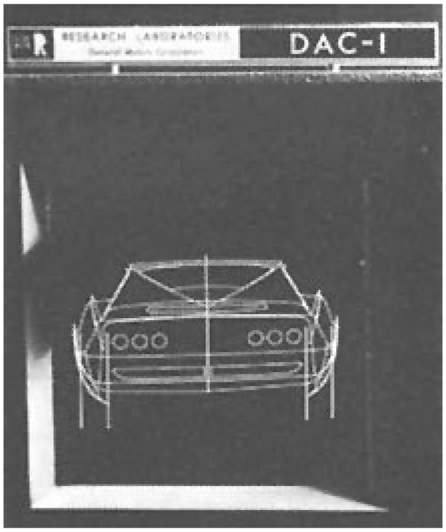
- The PDP 11/45 was featured in a *Doonesbury* comic strip in 1971.
- In 1977, Ken Olsen, founder of DEC, is said to have commented about PCs “There is no reason for any individual to have a computer in his home.”

# 3.3 General Motors DAC

Beginning in 1959, General Motors and IBM embarked on a project to create a unified computer assisted design environment. Originally called "Digital Design", its name was changed to DAC, for *Design Augmented by Computer*. It was formally disclosed at the 1964 Fall Joint Computer Conference. Called **DAC-1**, the first system was built by IBM using specifications provided by a team of engineers from General Motors, including Fred Krull and Dr. Patrick Hanratty, who later founded the **CADD** company MCS. The display system, sometimes considered as the first **CAD** system, introduced transformations on geometric objects for display, including rotation and zoom, and a no-display (later called "**clipping**") function (see automobile image at the right). It used a light pencil, instead of the commonly used light gun or **light pen**. This device read coordinate voltages from a conductive transparent sheet that was positioned over the IBM Alpine display head.

*DAC-1 (Source: http://www.computerhistory.org/timeline/?category=gg )*

The Joint Computer Conference was held twice a year in Fall and Spring, and was a conference of a federation of the major computer societies, the American Federation of Information Processing Societies (AFIPS). It was held until 1973 when it was replaced by the National Computer Conference.



*DAC Display*

The DAC-1 display console was connected to an IBM 7094 computer. It utilized a very creative group design collaboration system, which consisted of a photo "readout" system connected to a projection device. When collaboration on the design drawing was desired, the operator could select a view which would be displayed on an auxiliary CRT film recorder, and it would be scanned and quickly processed, and could then be projected onto the screen. These components are all shown in the image of the system on the previous page. DAC-1 also could input drawings from other sources, such as traditional hand drawings, using a computer controlled film reader.

**Movie 3.3** General Motors DAC-1 Demo

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/DAC-1demo-1.m4v

*This excerpt from a DAC demonstration video shows General Motors engineers interacting with the design system.*

The technology developed in the DAC project at GM resulted in the development by IBM of (among other things) the workhorse IBM 2250 graphics display, which was the interface with the IBM 1130 and 360 mainframes, and which was one of the most commonly used graphics displays of the 1960s and early 1970s. The 2250 was a vector device with 1024×1024 addressable resolution, a 12×12 inch display screen, and a .0200 inch spot size. The model 1 had a storage buffer of 8,192 bytes and a cycle time of 4 ms per byte. It had 64 non-changable characters in a built in character generator for on-screen labeling. Like many display units to follow, the 2250 had a function keyboard, an alphanumeric keyboard and a light pen. Its basic cost was around $100K. More detailed information can be obtained from an article by Arthur Appel, et al from IBM in 1968.

IBM developed three graphics related devices for DAC-1 — the 2250 display device, the 2280 film recorder, and the 2281 film scanner. The last two were discontinued because they were not received well in the industry.

*IBM 2250 Display*

*Toward a Machine with Interactive Skills*, from Understanding Computers: Computer Images, Time-Life Books, 1986

*The Origin of Computer Graphics within General Motors*, Fred Krull, IEEE Annals of the History of Computing, Fall 1994 (Vol. 16, No. 3); Interactive Graphics for Computer-Aided Design, by M. David Prince, Addison Wesley, 1971.

*Aspects of Display Technology*, Arthur Appel, IBM Systems Journal, Volume 7, Numbers 3/4, Page 176 (1968)

The complete General Motors Research Laboratories movie about DAC-1 can be viewed at? http://excelsior.biosci.ohio-state.edu/~carlson/history/moovees/GM_Design_complete.m4v

# 3.4 Other output devices

Other significant display devices and systems were also introduced around the same period. Many people believe that the Adage was the first stand alone computer-aided design workstation. The Adage display had the advantage of extremely high speed (for the time) display rates, allowing for the representation of moving objects and flicker free rotations. The Adage AGT-30, like the IBM 2250 became a mainstay in graphics labs around the world.

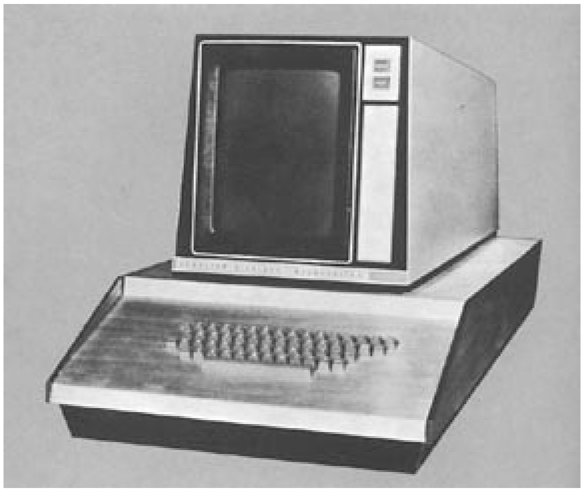
*Adage Display*

In a 1998 paper in the IEEE Annals of the History of Computing, Don Bissell notes that the IDIIOM CAD workstation, running the IDADS CAD software, actually preceded the Adage workstation, being introduced earlier in 1967 than Adage. Therefore, according to Bissell, "…one must respect IDIIOM's claim to historical primacy" as the first stand-alone CAD platform.

The ITEK Corporation involved personnel that got their start in the SAGE program at MIT (in particular, Thurber Moffett and Norm Taylor), and in fact was located near the Lincoln Labs facility. The ITEK project was to design optical lenses, and resulted in a system called The Electronic Drafting Machine (EDM). The EDM used a DEC PDP-1 computer from Digital Equipment Corp., a vector-refresh display and a large disk memory device used to refresh the graphic display. Input commands were done with a light pen. The EDM was developed in 1961 and was reported on in Time Magazine, March 2, 1962.

> "Technology: … to beat the language barrier between man and machine, ITEK has, in effect hitched the digital computer to the draftsman's stylus. With a photoelectric light pen, the operator can formulate engineering problem's graphically (instead of reducing them to equations) …".

Itek marketed the EDM machine and it was later sold to Control Data Corporation. It was marketed as the CDC Digigraphics System and it was heavily used in the aerospace industry at such companies as Lockheed and Martin Marietta. One of the more pricey systems, the Digigraphics system was available for approximately $500K.



Computer Displays, Inc. ARDS display

Other display devices included the storage tube display, such as the Computer Displays, Inc. ARDS and the Tektronix 4010 devices. Tektronix invented the direct view storage tube (DVST) vector graphics approach in 1965, and dominated the market for the next 15 years. They actually used their 564 storage tube oscilloscope as a computer graphics display in timeshare systems. Their 601 and 611 models introduced in 1967 were the first in their product line designed specifically for CG display. (They sold for $1050 and $2500, respectively.) The CDI ARDS (Advanced Remote Display System) actually used the Tektronix 611 6×8 storage tube, as did other systems like the Computek Display System. They were priced in the $12K range. The first commercial model from Tektronix was the 4002A, which was priced at about $9K.

Tektronix 4010 Display

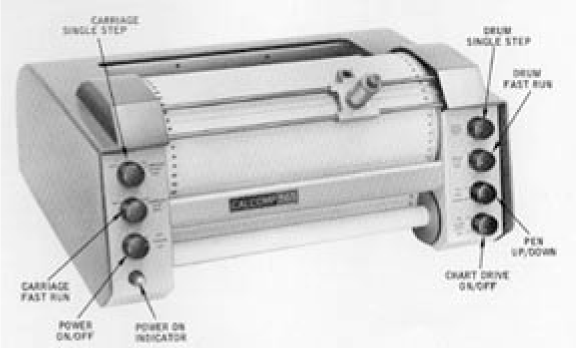
*Tektronix 4002A Direct View Storage Tube Display*

One problem with refresh vector displays is that they must continuously redraw the image on the screen, fast enough that the image doesn't "**flicker**". **Storage tube vector graphics** terminals differ from refresh vector graphics terminals in that the display maintains a "history" of what is drawn on the screen and therefore doesn't need to be refreshed. Only when the image changes does it need to be redrawn. For example, one storage tube approach uses two electron guns – one draws lines on the screen, the other bathes the entire display in electrons at a lower intensity. This second beam keeps any phosphor that has been activated continuously illuminated. However, it cannot erase anything except by clearing the entire screen. This last issue (no dynamic capability and the inability to update without erasure of the entire screen) coupled with the low light output made it not as popular for CG people as the refresh tube.

When large quantities of semi-permanent information such as maps had to be combined with dynamic or variable data, a system such as the rear projection CRT display was used. For example, the Bunker Ramo display could project color or black and white film images onto the screen of the CRT with a compensated, off-axis projector. The dynamic data was drawn using the electron gun of the CRT.

*Bunker Ramo rear projection CRT*

Other output devices included the **charactron** and the plotter. The charactron used a stencil mask within the CRT to efficiently draw characters on the screen. It was also used in several film recording devices, such as the Stromberg Carlson 4020 from General Dynamics. More discussion of the film recorder will take place in the sections on CGI production facilities. The first plotter developed was the CalComp 565, developed in 1958. The 565 was a high-speed drum-type XY plotter driven by step motors. Each step caused the pen to move horizontally (relative to the paper) a fixed increment (0.1 mm) in either a positive or negative direction at a rate of 250 steps per second. The drum provided the vertical movement. A solenoid permitted the pen to be lifted or lowered onto the paper. CalComp was incorporated in 1958, and introduced the 565 shortly thereafter. In 1986, CalComp became a unit of Lockheed after the company purchased Sanders Associates.



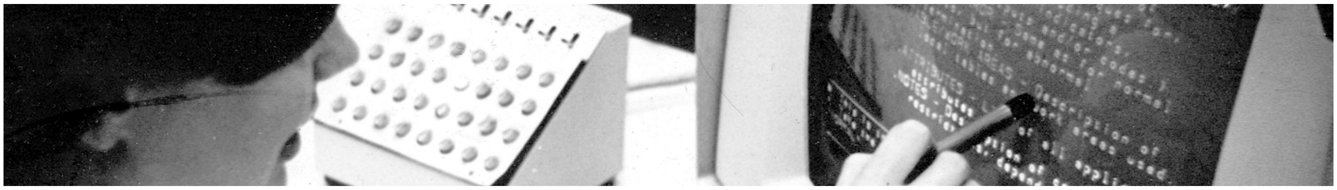
*Calcomp 565 drum plotter*

The **plasma panel** was a technology developed at the University of Illinois in 1964, as part of the PLATO automated teaching system. The technology used arrays of cells filled with neon gas, sandwiched between glass. Capacitors at each cell provided the driving circuitry to address and activate each cell. The plasma panel was patented in 1971 and sold to Owens-Illinois, who developed displays for use with the PLATO system. Later, Japanese and U.S. companies licensed the technology for computer graphics displays, but the technology failed to displace the CRT technology.

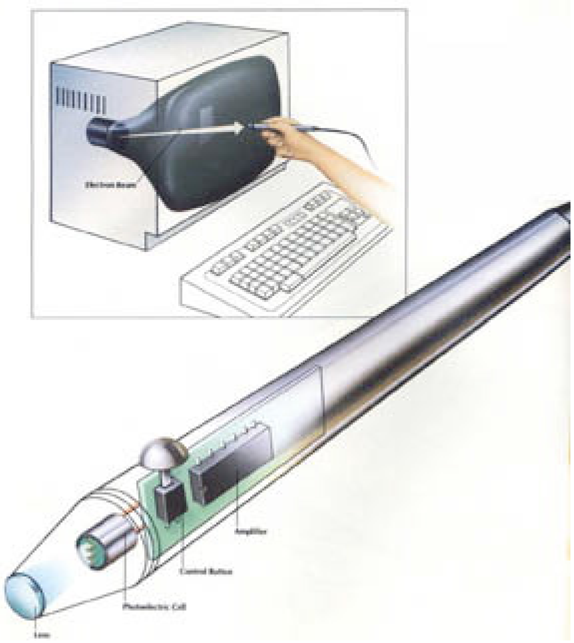
See "*A Colorful History of an Illinois Technology*" at
*http://web.archive.org/web/20051001030137/http://www.ece.uiuc.edu/alumni/w02-03/plasma_history.html*

Machover, Carl *Computer Graphics Terminals – A Backward Look*, SJCC 1972.

# 3.5 Input devices

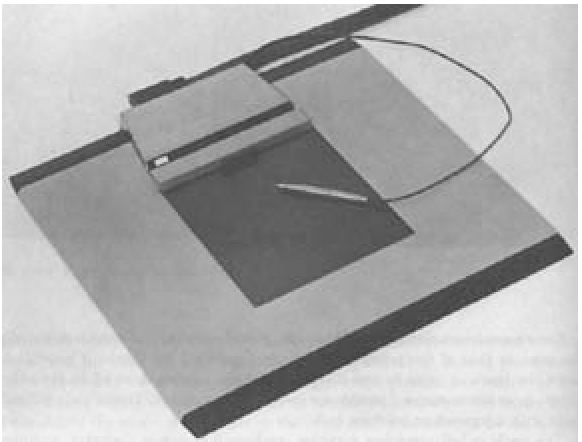


Input devices were also a very important part of the systems that were evolving during this early part of CG history. As mentioned earlier, typical input was accomplished with an alphanumeric terminal, function buttons and/or dials, and the **light pen** (or light pencil, in the case of the DAC-1 system). Also, the DAC-1 system pioneered the use of photographic input (what would later give rise to scanning technology.) The joystick was adapted to provide numerical input.



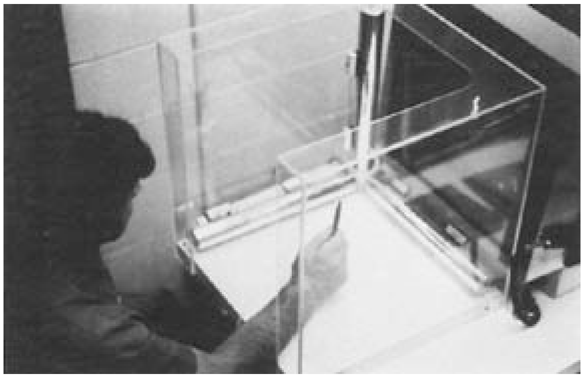
*Light Pen (Source: Understanding Computers: Computer Images, Time-Life Books, 1986)*

Tom Dimond patented an approach to handwriting recognition in 1957 that utilized an innovative tablet that detected the regions of interaction, giving rise to the **graphics tablet**. Sylvania introduced a tablet that operated on analog voltage principles. One of the most innovative input approaches at the time was manifested by the Rand Tablet. It consisted of a matrix of crossed conductors. The circuitry of the tablet used switching techniques to apply pulses to the conductors in sequence, thus coding their individual locations. When a stylus was touched to the surface of the tablet, it picked up pulses capacitively from the closest of the horizontal and vertical conductors which was converted into an (x,y) coordinate value. The tablet was marketed commercially as the Grafacon tablet, and was often bundled with early DEC computers. It was priced around $18K.



*RAND Tablet*

A variation on the graphics tablet approach to input was the sonic pen input tablet introduced in 1970. This technology used three microphones, positioned perpendicularly in the same configuration as the cartesian coordinate axes. A stylus generated a sound, for example with a spark generator, and the position was determined by the triangulation of the distances determined by the microphones. A three dimensional (x,y,z) coordinate resulted from the input. The sonic pen device shown here being used by Charles Csuri was developed at The Ohio State University, and it is being used here to control an image on the screen of a Vector General graphics display behind it. It was also used to "trace" three dimensional objects or paths.



*Chuck Csuri using OSU Sonic Pen*

In 1963, **Douglas C. Englebart** was working at the Stanford Research Institute. He set up his own research lab, which he called the Augmentation Research Center. Throughout the 1960s and 1970s his lab developed an elaborate hypermedia groupware system called NLS (oNLine System). NLS facilitated the creation of digital libraries and storage and retrieval of electronic documents using hypertext. NLS used a new device to facilitate computer interaction — the mouse. The design of the mouse included two opposing rollers set in the bottom of a block of wood. As it was rolled over a surface, the distance and the speed of the rollers inside the block could be sensed and returned to the computer to which it was attached. It could therefore control how a tracking cursor on the display moved and was positioned. A selector button on top could be pressed, defining an event that the computer could use to identify the position of the tracking cursor at the time of the event.

On December 9, 1968, Engelbart and the group of 17 researchers working with him in the Augmentation Research Center at Stanford Research Institute presented a 90-minute live public demonstration of the online system, NLS, they had been working on since 1962. The public presentation was a session in the Fall Joint Computer Conference held at the Convention Center in San Francisco. This was the public debut of the computer mouse. But the mouse was only one of many innovations demonstrated that day, including hypertext, object addressing and dynamic file linking, as well as shared-screen collaboration involving two persons at different sites communicating over a network with audio and video interface. This demonstration has become known as “the mother of all demos” at the Joint Computer Conference. The entire 90 minute demo, in 35 sections (Section 12 of the demo describes the mouse), is online at http://sloan.stanford.edu/mousesite/1968Demo.html

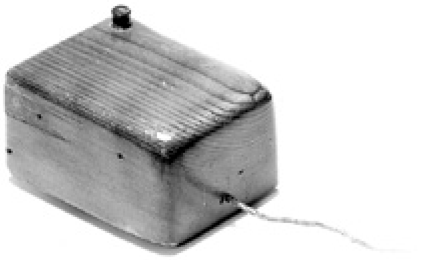
*Englebart mouse prototype*

*http://www.computerhistory.org/revolution/input-output/14/intro/1876*

The following quotation from Engelbart is from an article titled The Click Heard Round The World, by Ken Jordan, in a 2004 issue of Wired Magazine.

> “The mouse we built for the [1968] show was an early prototype that had three buttons. We turned it around so the tail came out the top. We started with it going the other direction, but the cord got tangled when you moved your arm. ?I first started making notes for the mouse in ’61. At the time, the popular device for pointing on the screen was a light pen, which had come out of the radar program during the war. It was the standard way to navigate, but I didn’t think it was quite right. ?Two or three years later, we tested all the pointing gadgets available to see which was the best. Aside from the light pen there was the tracking ball and a slider on a pivot. I also wanted to try this mouse idea, so Bill English went off and built it. ?We set up our experiments and the mouse won in every category, even though it had never been used before. It was faster, and with it people made fewer mistakes. Five or six of us were involved in these tests, but no one can remember who started calling it a mouse. I’m surprised the name stuck. ?We also did a lot of experiments to see how many buttons the mouse should have. We tried as many as five. We settled on three. That’s all we could fit. Now the three-button mouse has become standard, except for the Mac.”

*Engelbart's workstation, showing an early version (c1964) of the mouse*



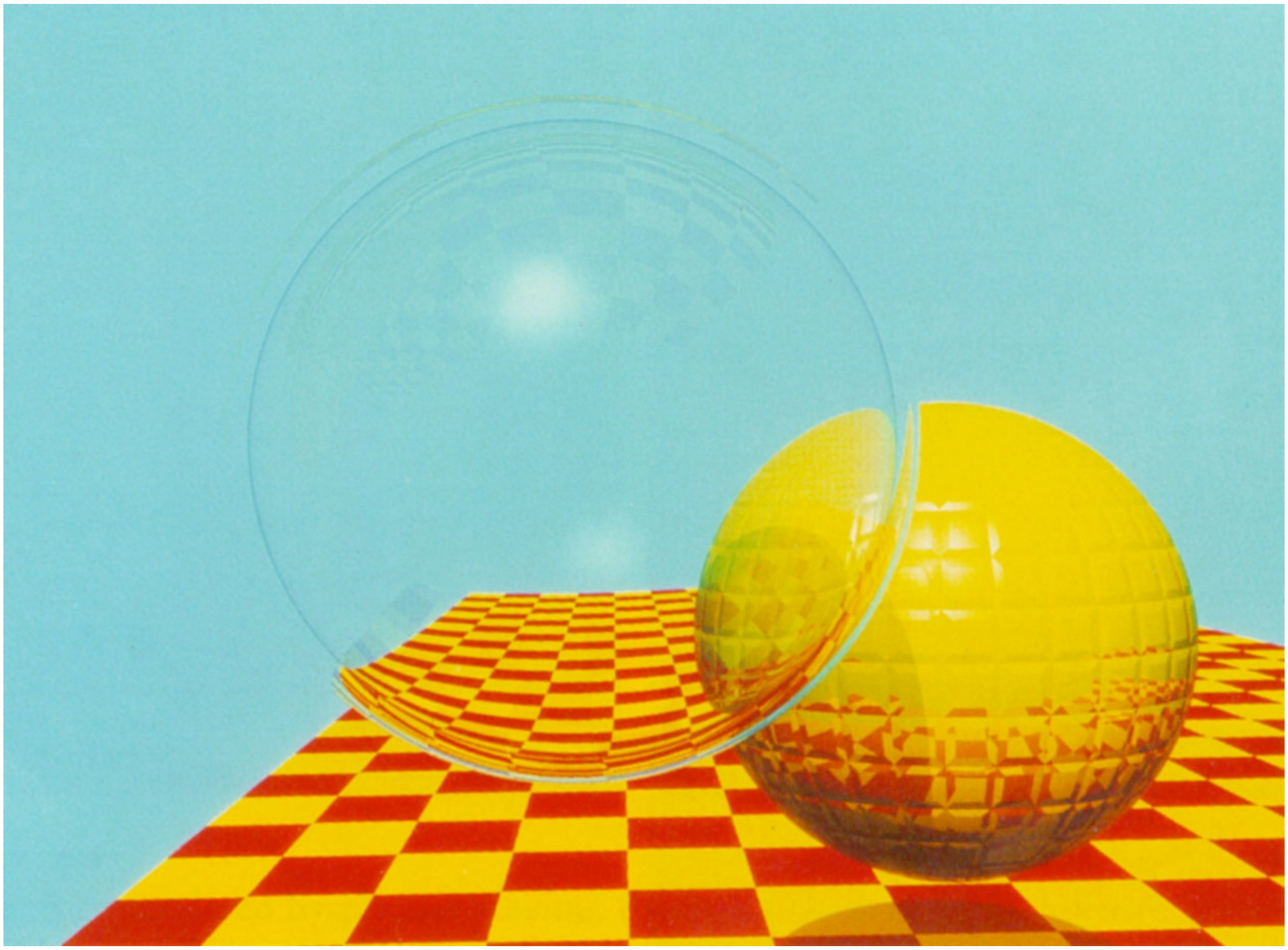
*Early Engelbart Mouse*

*http://www.livinginternet.com*

# Chapter 4: Basic and applied research moves the industry

# Basic and applied research moves the industry

Researchers at universities and laboratories around the world began to investigate techniques that could harness the power of the computer and its display and interaction devices to solve problems and provide capabilities that may have been outside of the reach of certain users because of the complexity of the programming process.

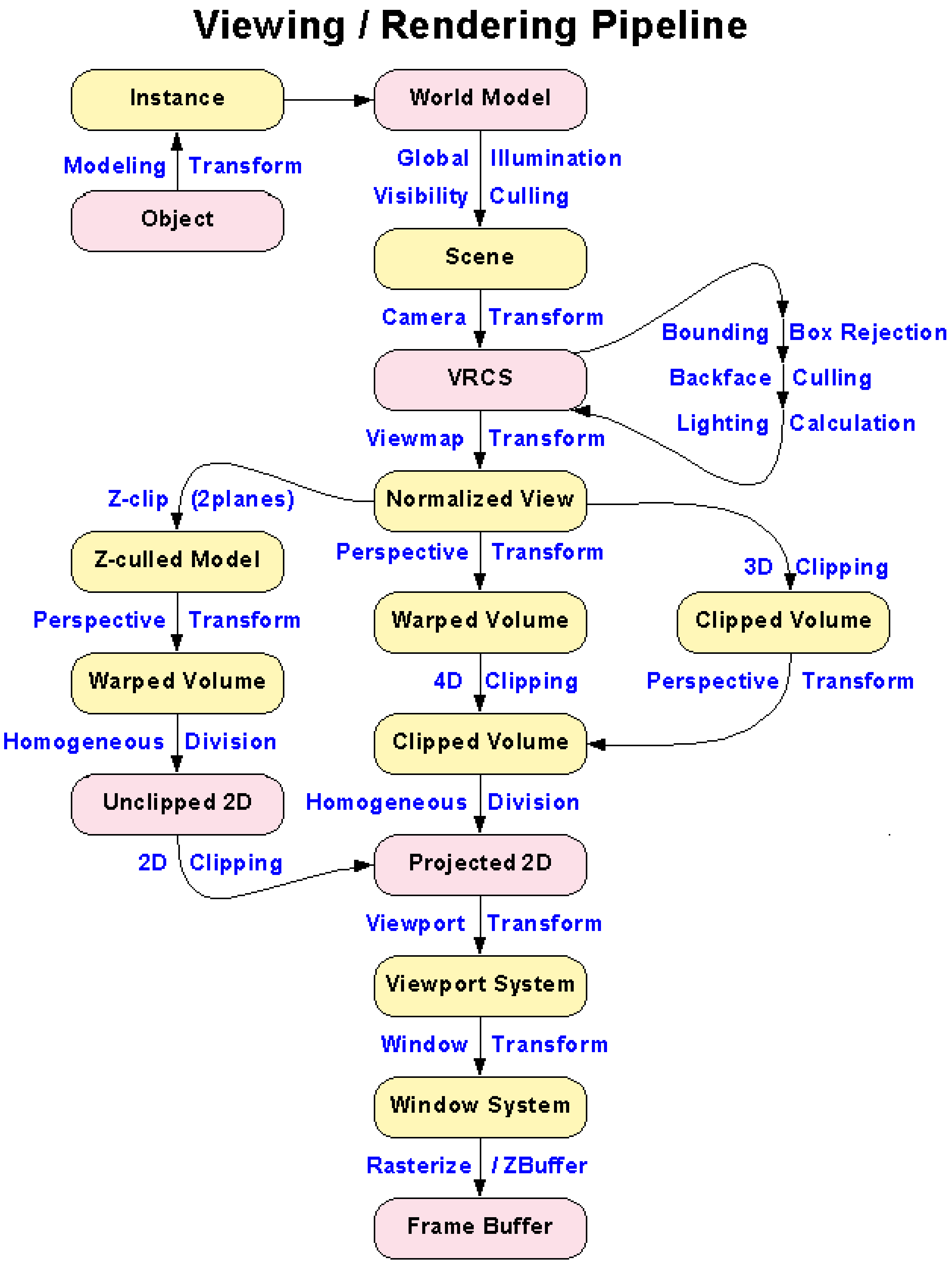


*Ray-Tracing, Turner Whitted (1980)*

# 4.1 Introduction

Much of the work in computer graphics to this point was centered around the development of solutions in the two dimensional (2D) realm. The creation of three dimensional (3D) models and images of them, while retaining accuracy of things like **foreshortening** and **perspective** and surface **rendering** were much more difficult. Some work at MIT, and companies such as IBM, Boeing, and General Motors was being done, but it took federal grants and investments to really push the evolution of the field. In particular, ARPA funding at the University of Utah and NSF funding at Ohio State, along with focused industry funding changed the direction of research.

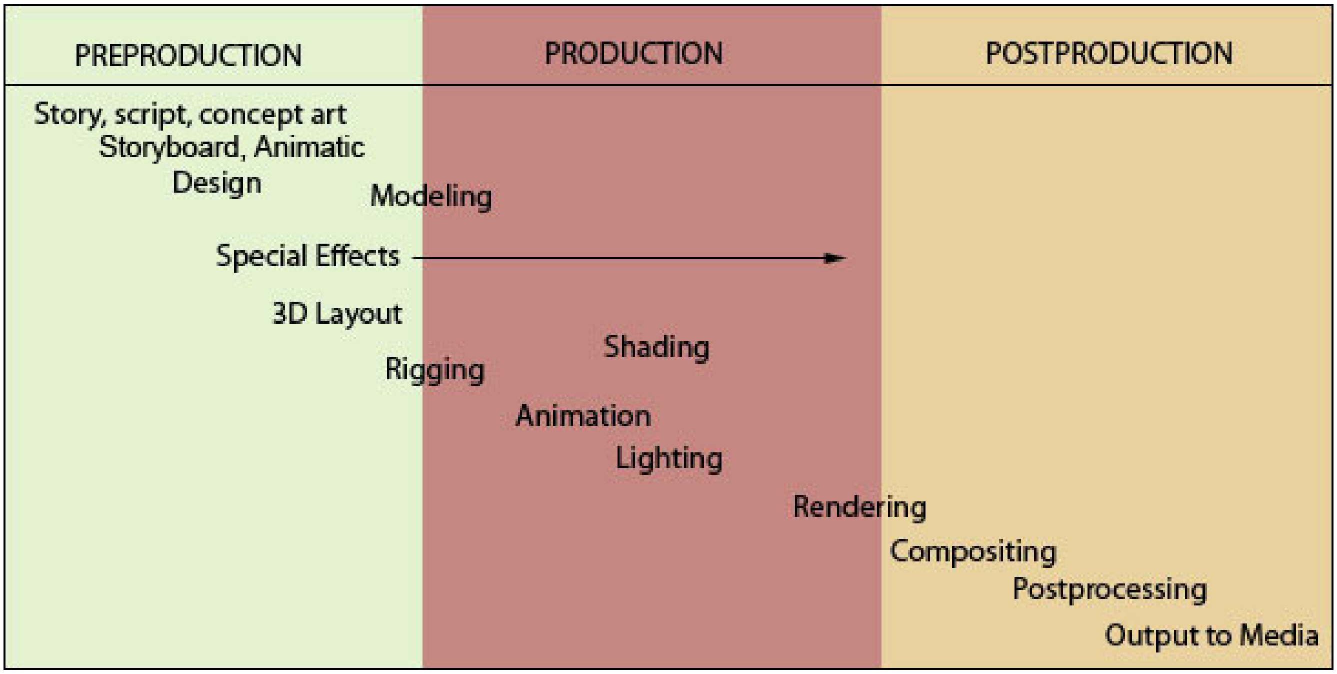
The next few chapters portray the work that was taking place in these labs, and the rapid results that came from it. To set the stage, it is valuable to look at the 3D image pipeline, which depicts the steps necessary to go from a conceptual idea with 3D geometric objects to an image depicting it displayed on the display monitor. The following chart shows the pipeline, as presented by Prof. Carlo Sequin at UC Berkeley.


Viewing / Rendering Pipeline
Instance
World Model
Modeling Transform
Object
Global Illumination
Visibility Culling
Scene
Camera Transform
Bounding Box Rejection
VRCS
Backface Culling
Lighting Calculation
Viewmap Transform
Z-clip (2planes)
Normalized View
Z-culled Model
Perspective Transform
3D Clipping
Perspective Transform
Warped Volume
Clipped Volume
Warped Volume
4D Clipping
Perspective Transform
Homogeneous Division
Clipped Volume
Unclipped 2D
Homogeneous Division
2D Clipping
Projected 2D
Viewport Transform
Viewport System
Window Transform
Window System
Rasterize / ZBuffer
Frame Buffer

3D Pipeline

While the specific details of the pipeline are beyond the scope of this book[1], the next few chapters will look at innovations in geometric modeling, perspective representation, surface detection and representation, and the rendering process. Many of these innovations resulted in significant systems, both software and hardware, and the rise of labs and companies that resulted.

When animation is added, the pipeline expands, as shown in this chart used at Ohio State's ACCAD program, based on the definition in Isaac Kerlow's book [2]. Later chapters deal with the animation and production of realistic images and image sequences.



3D Animation Production Pipeline

One of the most difficult and time consuming components of the pipeline is the generation of complex 3D models. In 1988, John Wright started a company in Orem, Utah, called Viewpoint Datalabs, to generate these models on consignment.

Viewpoint Logo

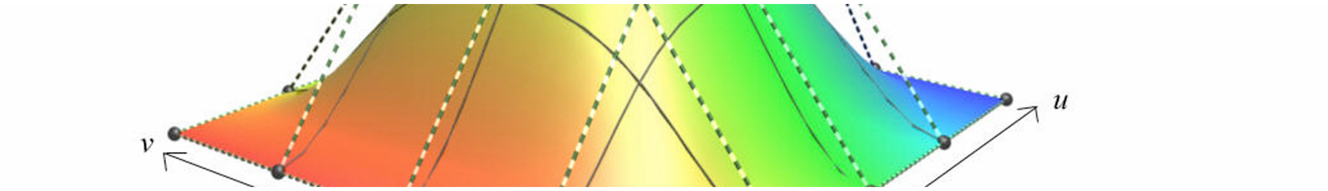
Viewpoint started as a company a that focused on accident reconstruction and courtroom visualization. Using the tools and techniques developed for that industry, they digitized models of objects including vehicles, animals, aircraft, architecture, sports, military, geography, human anatomy and more, which they delivered on DVD. The models on the disc were of four levels of detail, from simple wireframe to fully textured. Customers ranged from ad agencies, to government agencies, to game developers, to production houses and film companies.

---

1. For more details, see Computer Graphics: Principles and Practice, by John F. Hughes, Andries van Dam, Morgan McGuire, David F. Sklar, James D. Foley, Steven K. Feiner, and Kurt Akeley. (Revised 3rd edition of original "Foley and van Dam"), Pearson Education, 2014.
2. The Art of 3D Computer Animation and Effects / Edition 4 by Isaac V. Kerlow. Wiley, 2009.

In 1998 the company was purchased by Computer Associates International, which sold the catalogue of 3D models to Digimation in 2002. Digimation's models have been used in production by companies such as Electronic Arts for games such as Need for Speed. It's models have been featured in motion pictures including The World Is Not Enough, Pushing Tin, Star Trek: Insurrection, Independence Day, Air Force One and Godzilla.

# 4.2 MIT and Harvard



The late 1950s and the decade of the 1960s saw significant development in computer graphics-related computing, displays, and input and output hardware. The nature of the computer at this point in history was that it allowed programs to be written to accomplish different functions. But in the early days of computer graphics, users purchased their hardware, and the burden of developing these reusable programs, often including the development of the underlying algorithms for creating images, fell on the shoulders of the individual user.

Researchers at universities and laboratories around the world began to investigate techniques that could harness the power of the computer and its display and interaction devices to solve problems and provide capabilities that may have been outside of the reach of certain users because of the complexity of this programming process. A software industry was spawned, and turnkey systems were marketed that buffered the individual user from the computer instructions necessary to use the system to its potential.

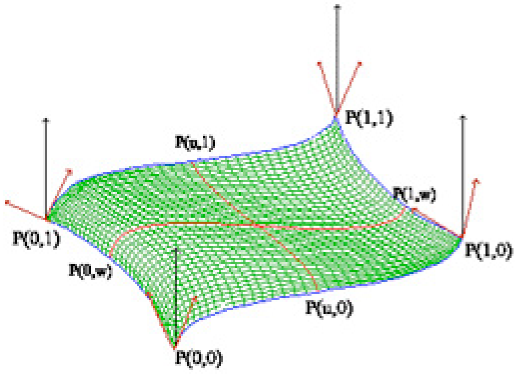
## MIT

Some of the early work in computer graphics related algorithm and software development took place at the Massachusetts Institute of Technology, and at Harvard University just up the Charles River.

Tom Stockham was at Lincoln Labs on a project to use computers to process photographic material. His technique was to use a facsimile machine to "**digitize**" a photograph so that each element of the picture (what would later come to be known as the **pixel**) could be represented as a number in memory that represented a shade of gray. Once he had this image in digital form, he manipulated properties such as dynamic range and contrast, and then re-photographed the image from the screen of a CRT. Hence, what is now common in software packages such as Photoshop, that is, image processing, was developed.

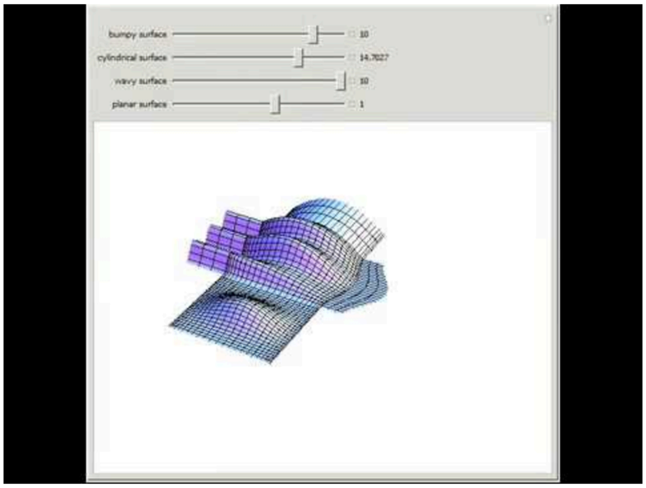
A professor in the Mechanical Engineering Department at MIT during the 1950s and 1960s, **Steven Coons**, had a vision of interactive computer graphics as a powerful design tool. During World War II, he worked on the design of aircraft surfaces, developing the mathematics to describe generalized "surface patches." At MIT's Electronic

Systems Laboratory he investigated the mathematical formulation for these patches, and in 1967 published one of the most significant contributions to the area of geometric design, a treatise which has become known as “The Little Red Book”.



*Graphic representation of the Coons’ patch. The curvature on the interior is controlled by the geometry at the edges and the corners, with the depicted vectors providing the controls.*

His “Coons Patch” was a formulation that presented the notation, mathematical foundation, and intuitive interpretation of an idea that would ultimately become the foundation for surface descriptions that are commonly used, such as b-spline surfaces, NURB surfaces, etc. His technique for describing a surface was to construct it out of collections of adjacent patches, which had continuity constraints that would allow surfaces to have curvature which was expected by the designer. Each patch was defined by four boundary curves, and a set of “blending functions” that defined how the interior was constructed out of interpolated values of the boundaries.


bumpy surface 10
cylindrical surface 14.7027
wavy surface 10
planar surface 1

***Movie 4.1*** *– Generalized Coons Surface, From Wolfram’s Mathematica demonstration*

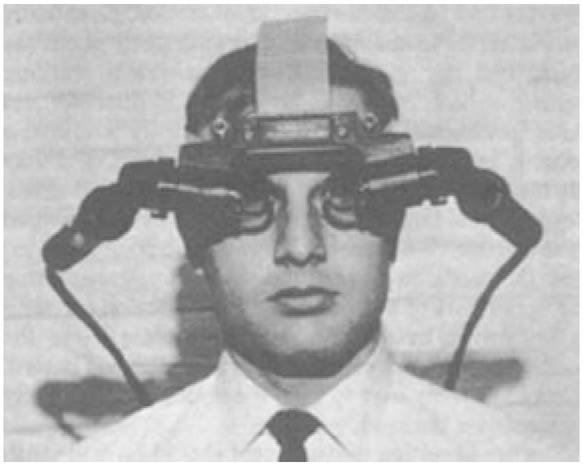
Two of Coons' students were Ivan Sutherland and Lawrence Roberts, both of whom went on to make numerous contributions to computer graphics and (in Roberts' case) to computer networks.

**Lawrence Roberts** wrote the first algorithm to eliminate hidden or obscured surfaces from a perspective picture. In 1965, Roberts implemented a homogeneous coordinate scheme for transformations and perspective. His solutions to these problems prompted attempts over the next decade to find faster algorithms for generating hidden surfaces, many of which were investigated at the University of Utah (Section 3 in this chapter).

## Harvard University

After leaving MIT, Ivan Sutherland went briefly to ARPA, and was then recruited by Harvard. There he engaged in studies to produce pictures with dynamic perspective. The following account of these research activities at Harvard is from *FUNDING A REVOLUTION : Government Support for Computing Research*, published by the National Research Council in 1999.

> In 1966, Ivan Sutherland moved from ARPA to Harvard University as an associate professor in applied mathematics. At ARPA, Sutherland had helped implement J.C.R. Licklider's vision of human-computer interaction, and he returned to academe to pursue his own efforts to extend human capabilities. Sutherland and a student, Robert Sproull, turned the "remote reality" vision systems of the Bell Helicopter project into VR by replacing the camera with computer-generated images. The first such computer environment was no more than a wire-frame room with the cardinal directions–north, south, east, and west–initialed on the walls. The viewer could "enter" the room by way of the "west" door and turn to look out windows in the other three directions. What was then called the head-mounted display later became known as VR.
>
> Sutherland's experiments built on the network of personal and professional contacts he had developed at MIT and ARPA. Funding for Sutherland's project came from a variety of military, academic, and industry sources. The Central Intelligence Agency provided $80,000, and additional funding was provided by ARPA, the Office of Naval Research, and Bell Laboratories. Equipment was provided by Bell Helicopter. A PDP-1 computer was provided by the Air Force and an ultrasonic head-position acoustic sensor was provided by MIT Lincoln Laboratory, also under an ARPA contract.



*Sutherland's Head Mounted Display*

> Sutherland outlined a number of forms of interactive graphics that later became popular, including augmented reality, in which synthetic, computer-generated images are superimposed on a realistic image of a scene. He used this form of VR in attempting a practical medical application of the head-mounted display. The first published research project deploying the 3D display addressed problems of representing hemodynamic flow in models of prosthetic heart valves. The idea was to generate the results of calculations involving physical laws of fluid mechanics and a variety of numerical analysis techniques to generate a synthetic object that one could walk toward and move into or around (Greenfield et al., 1971).
>
> As Sutherland later recalled, there was clearly no chance of immediately realizing his initial vision for the head-mounted display. Still, he viewed the project as an important “attention focuser” that “defined a set of problems that motivated people for a number of years.” Even though VR was impossible at the time, it provided “a reason to go forward and push the technology as hard as you could. Spin-offs from that kind of pursuit are its greatest value.”
>
> Several of the original Harvard group also helped form [Evans and Sutherland], including Charles Seitz, who joined the Utah faculty in 1970 and remained until 1973, when he moved to California Institute of Technology and founded Myricom with Dan Cohen, another Harvard alumnus who contributed to the head-mounted display. The interaction between research on basic problems and development of hardware and software for military projects at Evans & Sutherland was an important feature of work at [the University of] Utah.

Sutherland’s group also developed the first **clipping** algorithm, eliminating any part of a synthetic environment that was outside the “camera’s” field of view, making it less computationally intensive to generate a scene on the screen.

William Newman was also at Harvard during this period. He was interested in the construction of command languages for interactive computer use. His ideas on command language programming have been very important in the evolution of the human-computer graphical interface. Newman was co-author with Robert Sproull of Carnegie Mellon of one of the most influential textbooks in the area of computer graphics, *Principles of Interactive Computer Graphics*, published by McGraw-Hill in 1973. Newman went on to continue his HCI work at Xerox PARC.

Coons, Steven A. 1967. Surfaces for Computer-aided Design of Space Forms , Project MAC Report MAC-TR-41. Massachusetts Institute of Technology, Cambridge, Mass. (*abstract*) (*full PDF*)

*Sutherland, I.E., Sproull, R.F., Schumaker, R., A Characterization of Ten Hidden Surface Algorithms*, ACM Computing Surveys, 6(1), 1974, pp. 1-55

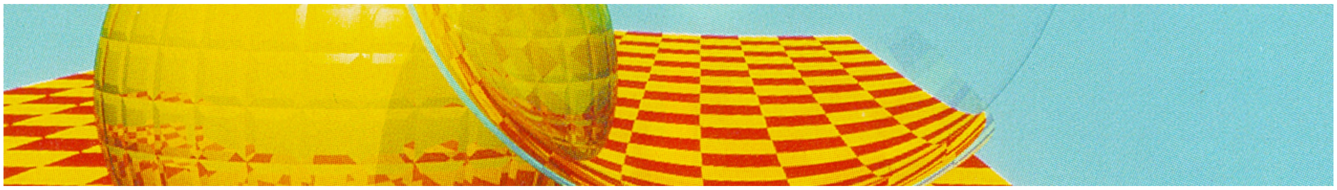
Roberts, L G., “Machine Perception of Three Dimensional Solids,” MIT Lincoln Lab. Rep., TR 315, May 1963.

Roberts, Lawrence G. 1965. Homogenous Matrix Representation and Manipulation of N-Dimensional Constructs, MS-1505. MIT Lincoln Laboratory, Lexington, Mass

*Retrospectives: The Early Years in Computer Graphics at MIT, Lincoln Lab and Harvard*, SIGGRAPH 89 Panel Proceedings

*FUNDING A REVOLUTION : Government Support for Computing Research*, published by the National Research Council in 1999.

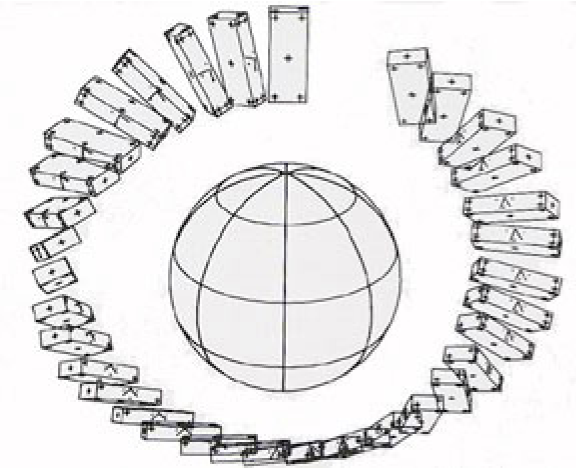
# 4.3 Bell Labs and Lawrence Livermore



## Bell Labs

Bell Telephone Laboratories in Murray Hill, N.J. was a leading research contributor beginning with its founding in 1925, and contributed research in computer graphics, computer animation and electronic music starting in the early 1960s. Initially, researchers were interested in what the computer could be made to do in areas such as speech and communications technology, but the results of the visual work produced by the computer during this period have established people like Michael Noll and Ken Knowlton as pioneering computer artists as well as scientists. (See *The Digital Computer as a Creative Medium*, by Michael Noll, IEEE CG&A, 1967)

Physicist **Edward Zajac** produced one of the first computer generated films in history while at Bell Labs. His work was first publicized in 1963. The animation demonstrated that a satellite could be stabilized to always have a side facing the earth as it orbited. This film was titled *A two gyro gravity gradient altitude control system*. The composite shown here uses a block to represent the satellite, with each frame showing the positioning relative to the earth.



At about the same time Ken Knowlton and Leon Harmon experimented with human pattern perception and art by perfecting a technique that scanned, fragmented and reconstructed a picture using patterns of dots (such as symbols or printer characters.) Their *Reclining Nude* (a representation of dancer Deborah Hay) was submitted to one of the earliest computer art exhibitions, *The Machine as Seen at the End of the Mechanical Age,* curated by K.G. Pontus Hulten, at the Museum of Modern Art in 1968.

*Cover of book "The Machine as Seen at the End of the Mechanical Age", by K.G. Pontus Hulten. The book has a printed metal cover.*

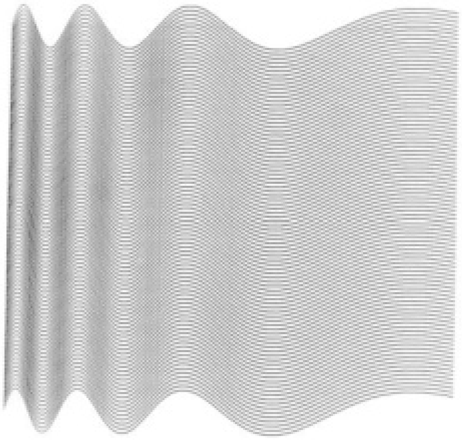
Ken Knowlton developed the *Beflix* (Bell Flicks) animation system in 1963, which was used to produce dozens of artistic films by himself and artists such as Stan VanDerBeek and Lillian Schwartz.

Ruth Weiss created in 1964 (published in 1966) some of the first algorithms for converting equations of surfaces to **orthographic** views on an output device. Her paper (Ref: Weiss, Ruth E., *BE VISION, a Package of IBM 7090 FORTRAN Programs to Drive Views of Combinations of Plane and Quadric Surfaces,* Journal of the ACM 13(4) April 1966, p. 194-204) was selected to be included in a 1998 compilation by SIGGRAPH of the seminal papers in computer graphics.

The artistic/scientific/educational image making efforts at Bell Labs were some of the first to show that electronic digital processing (using the IBM 7094 computer) could be coupled with electronic film recording (using the Stromberg-Carlson SC-4020 microfilm recorder) to make exciting, high resolution images. With the dozen or so films made between 1962 and 1967, and the many more films after that, they also showed that computer animation was a viable activity. Zajac's work, Frank Sinden's films (eg, *Force, Mass and Motion*) and studies by Michael Noll in the area of stereo pairs (eg, *Simulated basilar membrane motion*) were some of the earliest contributions to what is now known as scientific visualization.

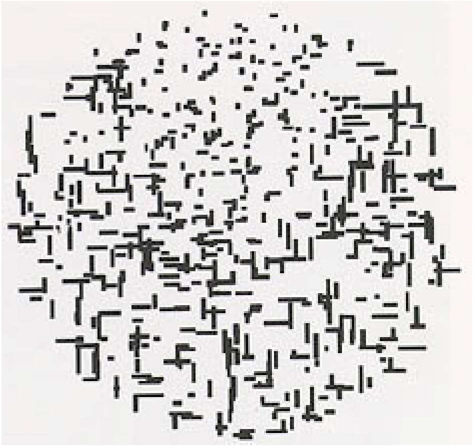
Noll and other Bell Labs researchers contributed some of the earliest computer artwork in the discipline, such as his *Gaussian-Quadratic* (1962), to the first formal exhibition of computer art in the United States in 1965. The exhibition was called “Computer-Generated Pictures” and was located at the Howard Wise Galleries in New York. Bela Julesz, also from Bell Labs, participated in the exhibition as well, showing his work in random dot stereograms. Later that year, Noll’s work from the Wise exhibition was shown at the Fall Joint Computer Conference (FJCC) of the American Federation of Information Processing Societies (AFIPS) in Las Vegas.

Some of Michael Noll’s early artwork revolved around an attempt to represent existing fine art on the computer. For example, one of his early computer generated images was a rendition of “Op-artist” Bridget Riley’s painting *Currents*, which Noll mimicked using a set of displaced sine waves.



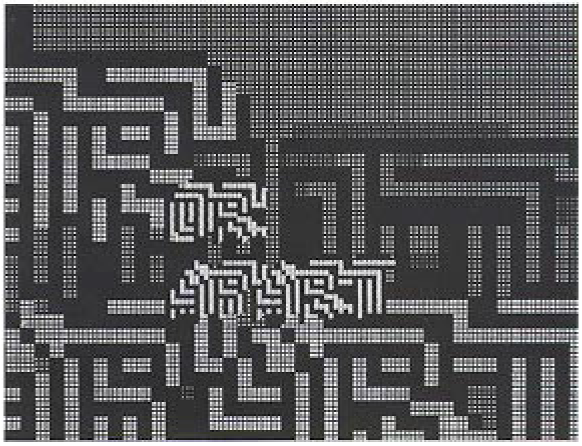
*Ninety Parallel Sinusoids with Linearly Increasing Period (after Currents) – Michael Noll*

He also “duplicated” Mondrian’s *Composition with Lines*, using visual representations generated with “random” numbers. The circular image was presented, along with a copy of the original, to a group of scientists at Bell Labs as a perception test. (The subjects actually preferred the computer generated version, which they also tagged as the most original.)

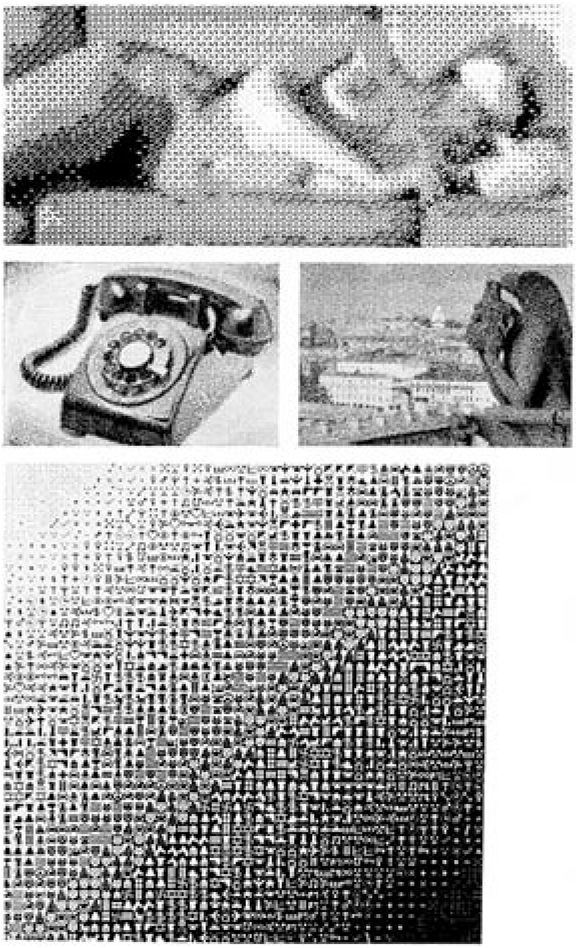


*Noll’s Mondrian experiment*

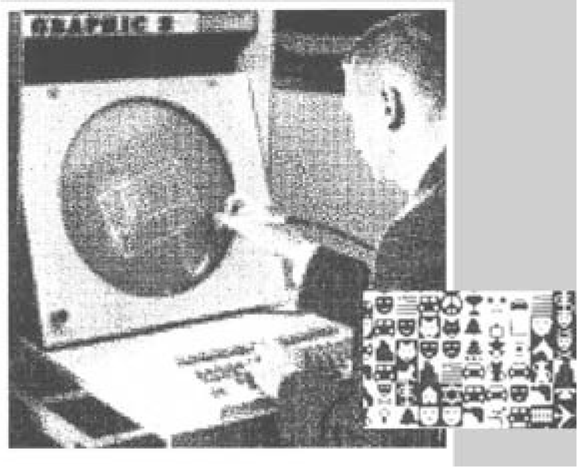
Other early “computer artists” (in addition to Noll, Knowlton, Schwartz, VanderBeek, Zajac and Harmon) working at or visiting Bell Labs were Manfred Schroeder, Laurie Spiegel, and Frank Sinden.



Vanderbeek and Schwartz



*Knowlton and Harmon*



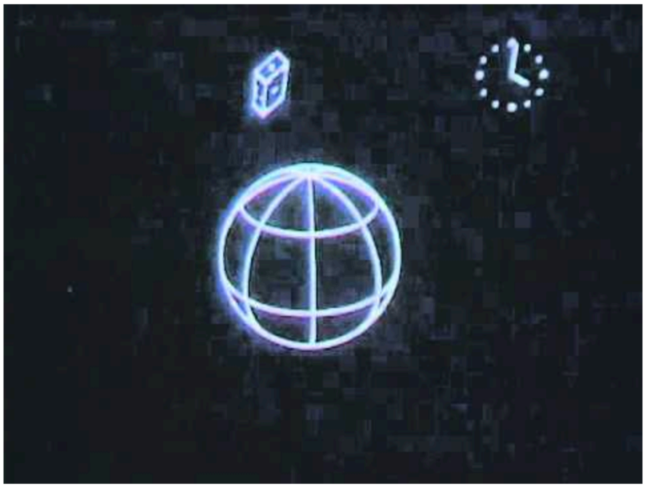
*Knowlton and Harmon*

**Movie 4.2** Scenes from *The Artist and the Computer*

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/schwartz-1.m4v

*This excerpt from The Artist and the Computer, a film by Lillian Schwartz, shows the computers and displays at Bell Labs.*

**Movie 4.3** Zajac Film



*A two gyro gravity gradient altitude control system* *https://www.youtube.com/watch?v=m8Rbl7JG4Ng*

**Movie 4.4** – *Incredible Machine*
*Incredible Machine* (1968) introduced by George Kupczak. A documentary of Bell Labs experimental advances in audiovisual communications

**Movie 4.5** – *A Computer Technique for the Production of Animated Movies*
*A Computer Technique for the Production of Animated Movies*, Ken Knowlton (1964). The use of BEFLIX in computer animated movies

**Movie 4.6** – *PoemField No. 2*
*PoemField No. 2* (1966) Knowlton and VanDerBeek

**Movie 4.7** – *Force, Mass and Motion*
*Force, Mass and Motion* (1965), Frank Sinden

**Movie 4.8** – *HyperCube/4D Hypermovie*
*HyperCube/4D Hypermovie* (1965) Michael Noll

*Computing Science Technical Report No. 99 : A History of Computing Research at Bell Laboratories (1937-1975)* by Bernard D. Holbrook and W. Stanley Brown

Noll, Michael, *The Beginnings of Computer Art in the United States: A Memoir*, Leonardo V27, #1

Weiss, Ruth E. *BE VISION, a Package of IBM 7090 FORTRAN Programs to Drive Views of Combinations of Plane and Quadric Surfaces*. Journal of the ACM 13(4) April 1966, p. 194-204.

*The Digital Computer as a Creative Medium*, by Michael Noll, IEEE CG&A, 1967

*A Computer Technique for Producing Animated Movies*, by Ken Knowlton, Proc. Spring Joint Computer Conference 1964.

*Early Digital Computer Art and Animation at Bell Telephones Laboratory, Inc*. – Michael Noll, May 2013

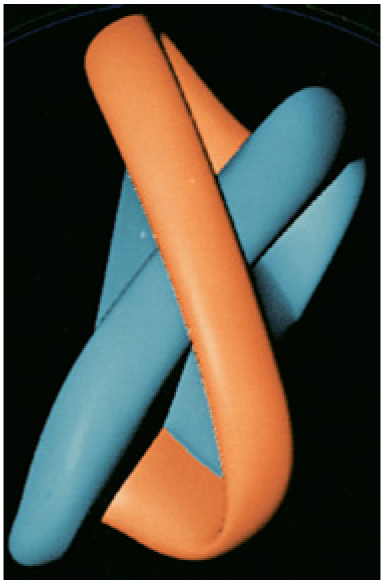
## Lawrence Livermore National Laboratories (LLNL)

Pioneering work in software for computer graphics and animation, mostly from an applications perspective, took place at Lawrence Livermore National Laboratories beginning in the early 1950s. Their interest in this technology was related to weapons research and areas such as particle dynamics and heat/fluid flow. They contributed immensely to the evolution of "big" computing, or what is now called **supercomputing**. George Michael, who started at the Lab in 1953 has put together an interesting oral history (although its coverage is much broader than CGI at LLNL) web page devoted to the story of the lab. It can be accessed at

*http://www.computer-history.info/*

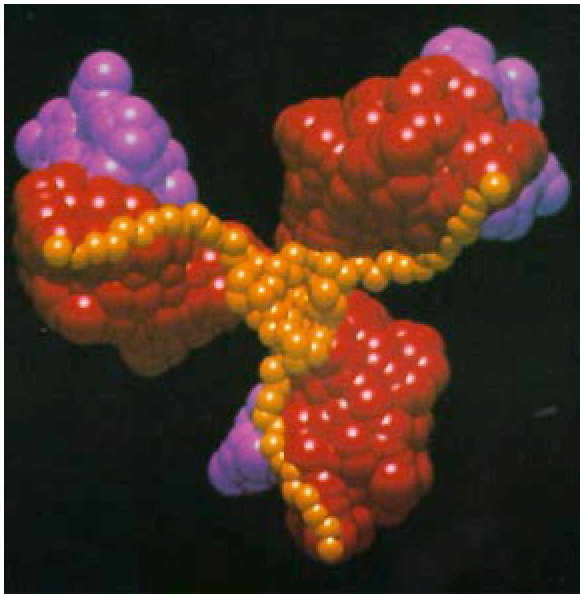
Steve Levine of LLNL wrote a paper for SIGGRAPH 75 describing the graphics activities there during that period. In particular, LLNL developed a direct-to-video recording capability that could complement their film recording processes. This video preview system was cheaper than video laser recording, and provided a unique and affordable method for looking at the animation that was produced there, before committing the time necessary to put it on film.

In another part of LLNL, **Nelson Max** worked as a researcher in computer graphics and animation. Max later also became a professor at the University of California, Davis/Livermore. His research interests focused on realism in nature images, molecular graphics, computer animation, and 3D scientific visualization. He served as computer graphics director for the Fujitsu pavilions at Expo ‘85 and Expo ‘90 in Japan.



*Nelson Max – frame from “Inversion of a Sphere”*

Nelson received his degrees in math from Johns Hopkins, and a PhD in topology from Harvard University. He was on the faculty at Carnegie Mellon in Pittsburgh, and Case Western in Cleveland and joined LLNL in 1977. His computer generated film from that year, T*urning a Sphere Inside Out* (International Film Bureau, Chicago, 1977) is one of the classic early films in the discipline. (See *Max’s remembrances* on the making of the film from the Annals of the History of Computing, and read his *SIGGRAPH 75 paper* here).



*Nelson Max molecular visualization*

At LLNL he also produced a series of molecular structure animations that have served to show the role of CGI in scientific visualization and generated wide acclaim for him. The most famous of these are *DNA with Ethidium* and *Intercalation with Doxorubicin/DNA*. He was also instrumental in the success of the IMAX movie *The Magic Egg* shown at SIGGRAPH 84 in Minneapolis.

*Nelson Max at the workstation, which has a frame from the movie "Carla's Island" displayed on it.*

**Movie 4.9** Carla's Island

*https://www.youtube.com/watch?v=kO-JB1WHmRc*
*Historical computer generated water, by Nelson Max (1981)*

Nelson Max, *My Six Years to Evert a Sphere*, IEEE Annals of the History of Computing, Vol. 20, #2, 1998.

*Computer Animation of the Sphere Eversion*, Nelson L. Max and William H. Clifford, Jr. Case Western Reserve University, Proceedings of SIGGRAPH 75.

*Computer Animation At Lawrence Livermore Laboratory*, S.R. Levine Lawrence Livermore Laboratory, Proceedings of SIGGRAPH 75.

Paul Heckbert, *Making The Magic Egg – A Personal Account*,
IEEE Computer Graphics and Applications, June 1986, pp. 3-8

**Movie 4.10** – Nelson Max DNA with Ethidium (1978)
*http://www.youtube.com/watch?v=TD0-2lkvfgU*

**Movie 4.11** – Nelson Max Intercalation of Doxorubicin with DNA (1980)
*http://www.youtube.com/watch?v=pCVsJ-maSa8*

# 4.4 University of Utah

**University of Utah**

The University of Utah established one of the pioneer, and certainly one of the most influential computer graphics programs in the country when they asked **David Evans** (who joined Utah in 1965) to establish a program that could advance the state of the art in this new field in 1968. The computer science department had received a large Defense Advanced Research Projects Agency (DARPA) grant ($5M/year for 3 years) which resulted in the work of many faculty and graduate students who have pushed the CGI discipline to where it is today. In the words of Robert Rivlin in his book *The Algorithmic Image: Graphic Visions of the Computer Age*, "Almost every influential person in the modern computer-graphics community either passed through the University of Utah or came into contact with it in some way."

Evans joined with Ivan Sutherland, who developed Sketchpad at MIT (see Section 4.1) and later served in a position at the Department of Defense, to create an environment in which new problems in the discipline were proposed, and in which creative solutions were found. They later founded the Evans and Sutherland Computer Company to develop and market CAD/CAM, design, molecular modeling and flight simulators.

After the 1957 launch of the USSR Sputnik satellite in 1957, ARPA invested in programs across the country to investigate diverse areas of scientific advancement that could help the United States remain competitive in advancing technology. The funding that they provided the University of Utah, which was the fourth node on the infant ARPAnet, was to investigate how the emerging field of computer graphics could play a role in this technological competitiveness. Evans convened an "eclectic group of faculty and students" (in the words of Ed Catmull[1]) to comprise a research environment that could respond to the agency's expectations. These researchers would define and address an astounding array of research problems in a relatively short period of time.

According to a summary of University of Utah documents[2]:

> The powerful resources at Utah were instrumental in attracting the very best faculty, students and collaborators to work with Evans on his vision. In recruiting Ivan Sutherland, Evans planned both his department and a company (Evans and Sutherland (Chapter 13.3), founded in 1968) that could develop interactive graphics workstations. Sutherland and Evans scoured the research community to attract the best talent among the skill sets required to build these systems. From MIT, they recruited engineering and signal/image processing talent, including faculty Thomas Stockham and Chuck Seitz, and Ph.D. students Donald Oestreicher and Alan L. Davis. From Ecole Polytechnique and other universities in France, they attracted the mathematical talent of students Robert Mahl, Henri Gouraud, Patrick Baudelaire, and Bui Tuong Phong.
>
> During the era of Evans and Sutherland, graduates of the Utah program made seminal contributions to rendering, shading, animation, visualization and virtual reality (notably the work of John Warnock in 1969, Henri Gouraud in 1971, Donald Vickers in 1972, Phong in 1973, Ed Catmull and Fred Parke in 1974, Henry Fuchs and Martin Newel in 1975, Frank Crow in 1976, Jim Blinn in 1978, Jim Kajiya in 1979, and many others). Additional graphics faculty hired during this time included computer artist Ron Resch (1970-1979) and Rich Riesenfeld, an expert in computer-aided geometric design (1972–present).
>
> In 1968, the equipment needed to produce an image representation was significant: a mainframe Univac performed the computations to produce the image, it sent its result to a PDP-8, which through analog output lines sent the image to a Tektronix oscilloscope to draw lines. A camera then recorded the image, without the image ever being displayed on a screen. Color images required several photos, each with a different colored filter. John Warnock, who received his Ph.D. in 1969, developed the first scientific visualizations using this approach. After Utah, Warnock moved to Evans and Sutherland, Xerox PARC, and then co-founded Adobe in 1982.
>
> The Utah Teapot is one of most iconic image in computer graphics. It was designed by Martin Newell, inspired by an actual Melitta teapot he purchased from a department store in Salt Lake City. Newell was a student of Evans, graduating in 1975, and then a member of the faculty from 1975 to 1977. Originally the teapot was sketched by hand using paper and pencil. Newell then edited bezier control points on a Tektronix storage tube. With this information he created a dataset of mathematical coordinates and a 3-D wire framing. The Utah Teapot was one of the first widely available and photogenic curved-surface 3-D models, an early

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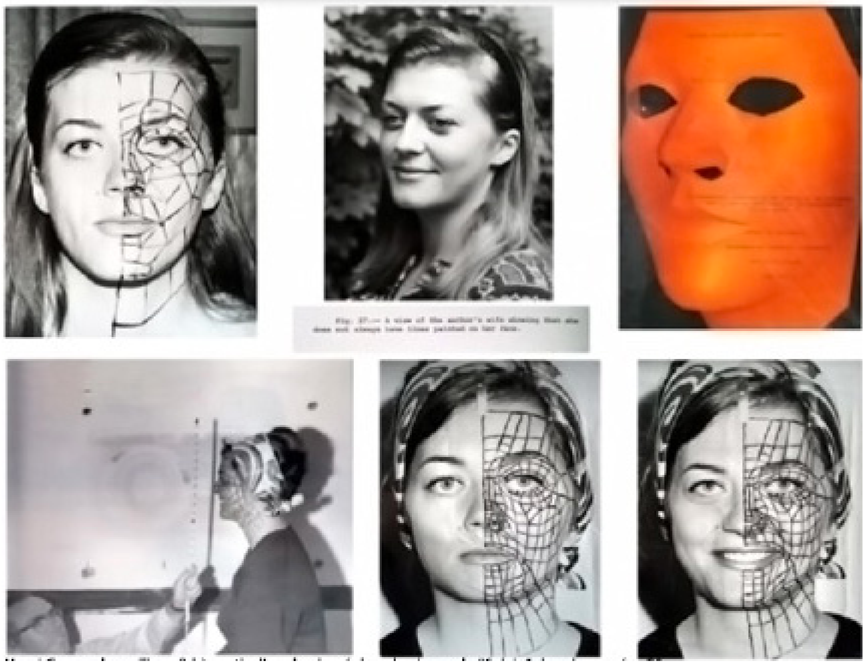
1. *Animation pioneer Ed Catmull wants the boss to get out of the way of creativity,* The Salt Lake Tribune, Apr 24 2017
2. https://en.wikipedia.org/wiki/University_of_Utah_School_of_Computing

high-quality virtual object. For this reason, it became a common benchmark model for image synthesis programs.

Utah students modeled other common objects. For his 1971 dissertation, Henri Gouraud developed Gouraud shading, using his wife Sylvie's face as a model.



In 1972, Ivan Sutherland challenged his graphics class to choose something iconic to realistically render. The students selected the Volkswagen Beetle—as a symbol of global culture, because it was large enough to measure as a group, and because Ivan's wife, Marsha, owned one. The students painted points and lines on the surface of the Beetle to describe a set of polygons. A volleyball stanchion and joints in the pavement formed a three-dimensional reference system. The points and polygons were rendered using hardware developed by 1970 Utah Ph.D. Gary Watkins to imprint shaded images onto a direct film recorder.[3]

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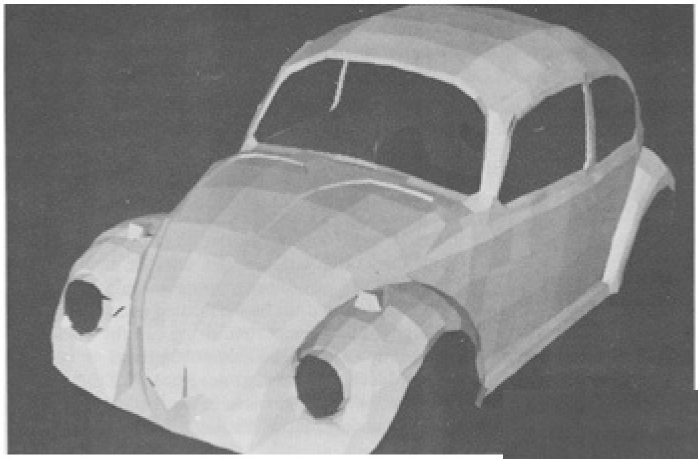
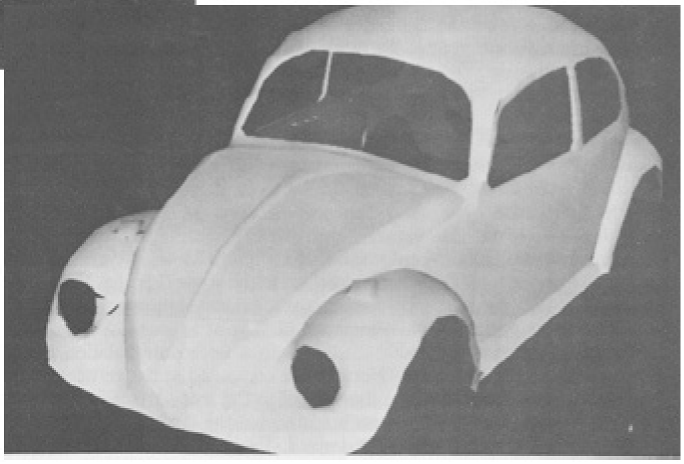
[3] *Robert [McDermott] Remembers: The VW Bug* - https://www.cs.utah.edu/docs/misc/Uteapot03.pdf





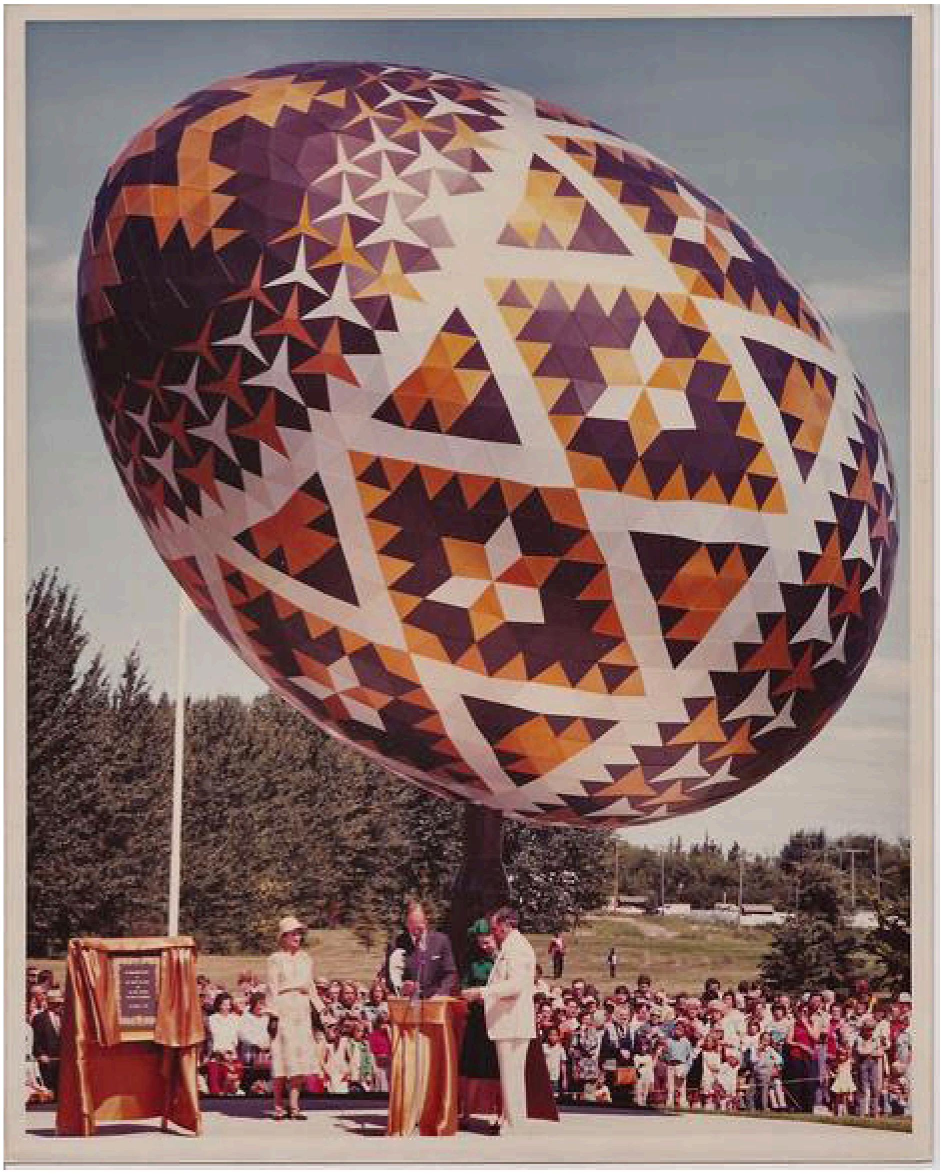
Also in 1972, Ed Catmull and Fred Parke, both students of Sutherland, made a video illustrating the process of modeling Catmull's left hand and its use in animation. Catmull made a plaster mold, to which he then added points and polygons in a similar way. Catmull received his Ph.D. in 1974, and went on to help found Pixar. The video (below) has recently been added to the National Film register as one of the earliest fully rendered computer animations. Parke also used the technique for facial speech modeling.

*Parke's faces*

**Movie 4.12** Halftone Animation (1972)

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/HandFace_1972.m4v

*Halftone Animation, by Ed Catmull and Fred Parke, demonstrates shading algorithms and early lip synching efforts.*



*Vegreville Pysanka, constructed of 2D aluminum tiles – Geometry solved by Ron Resch and Robert McDermott*

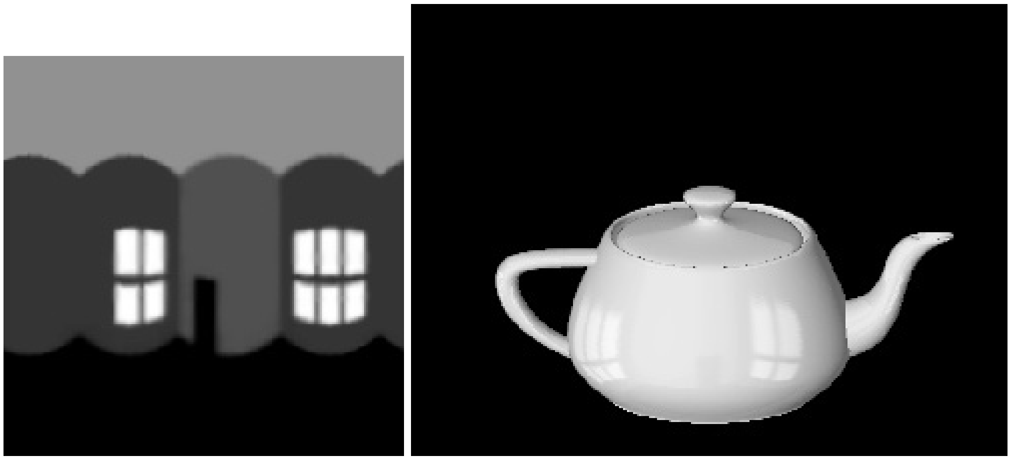
Ron Resch was on the faculty at Utah, and was contacted by a friend from Canada to help with a geometry problem that was facing a sculptor who was designing a monument to the Royal Canadian Mounted Police in 1975. The idea was to create a large (25′) egg that was reminiscent of a pysanka, or Ukranian Easter egg. Resch used early CAD design software that was being developed in the Utah lab to create a design using 524 stars and 1108 equilateral triangles out of anodized aluminum that were assembled into the 3D egg. The sculpture is located in Vegreville, Canada.

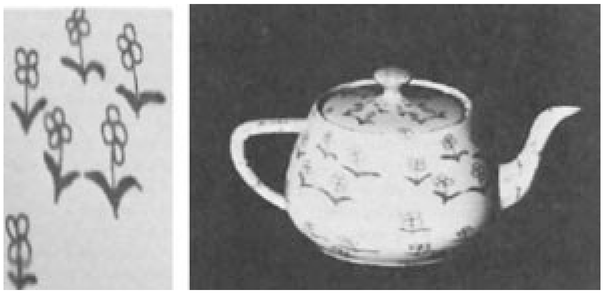
Some of the many important algorithms and theoretical results to evolve from the research in the Utah CG group include:

- *Hidden surface* (Romney, Warnock, Watkins)
- *Scan line coherence* (Watkins)

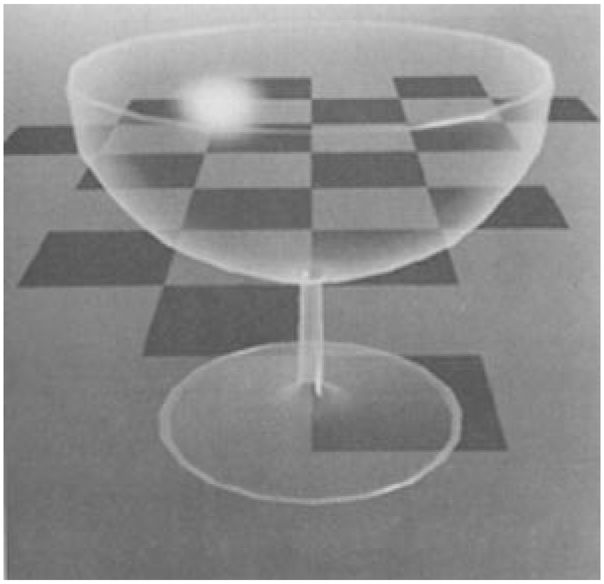
- Rendering (Crow, Blinn, Newell, Catmull, *Clark*, et al)
- *Texture mapping* (Catmull, Blinn, Newell)
- Environment mapping (*Blinn, Newell*)
- *Patch rendering* (Catmull, Clark)
- *z-buffer* (Catmull)
- *Shadows* (Crow)
- *Antialiasing* (Crow)
- *Shading* (Phong, Gouraud)
- Lighting (Phong, *Blinn*)
- Atmospheric effects (*Blinn*)
- *Blobby surfaces* (Blinn)
- *Facial animation* (Parke)
- *Procedural modeling* (Newell)
- Splines (Riesenfeld, Lyche, Cohen)
- Beta-splines (Barsky)

and many others. Many of these algorithms have resulted in the generation of significant hardware implementation, including LDS-1, the SGI Geometry Engine, the Head Mounted Display, the modern frame buffer, flight simulators, etc.

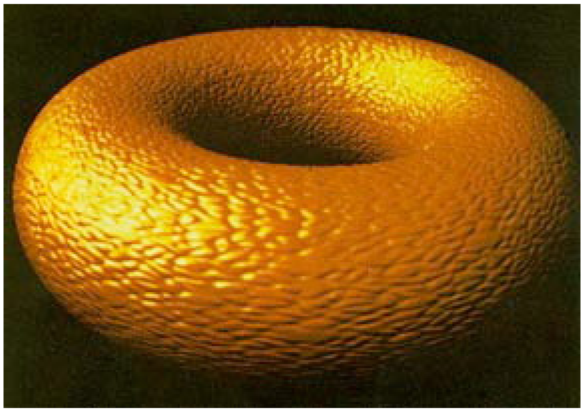




*Texture maps and reflection maps from Ed Catmull's dissertation*



*Phong shading on transparent glass*



*Jim Blinn – bump mapping*

One of the early "**motion capture**" systems was developed at Utah by Robert Burton in Sutherland's lab. Called the Twinklebox, the system used a collection of LEDs, which could be illuminated in rapid succession under computer control, and an elaborate scanning mechanism, consisting of a spinning disk with narrow radial slits and lenses. The scanning discs, positioned in the corners of the room, allowed the system to create a series of one dimensional scans of the environment, including the lights. Using a mathematical process, these scans were combined to determine 3D positions for each of the lights.

The early facilities at Utah included two PDP-10 computers, one of which used the TENEX multi-access system, while the other remained a single access computer. The head mounted display developed by Sutherland at Harvard was interfaced to the single access computer, as was the Twinklebox. A hardware implementation of the Watkins algorithm was used for display, and the LDS-1, developed by E&S was also connected to the PDP-10. This entire environment was connected to the new ARPA network.

A well known contribution of the Utah group was the Utah Raster Toolkit, developed by Spencer Thomas, Rod Bogart and John Peterson. The Utah Raster Toolkit was a set of programs for manipulating and composing raster images. The tools were based on the Unix concepts of pipes and filters, and operated on images in much the same way as the standard Unix tools operated on textual data. The Toolkit used a special **run length encoding** (RLE) format for storing images and interfacing between the various programs. This reduced the disk space requirements for picture storage and provided a standard header containing descriptive information about an image.

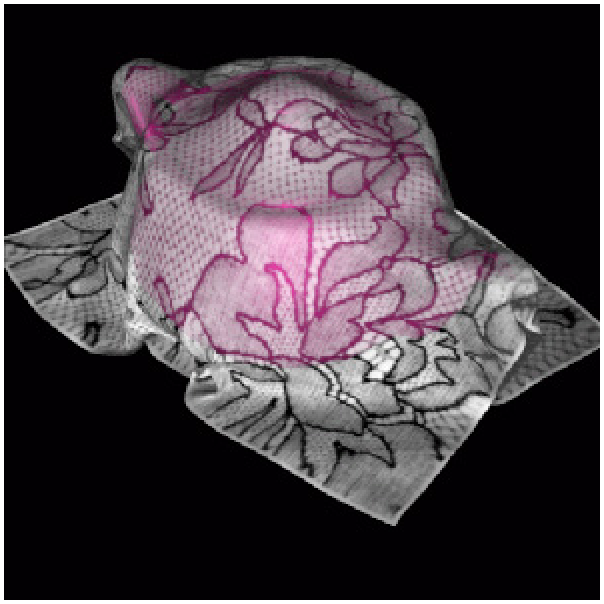
Individuals who were involved in the Utah program have established many leading companies in the graphics industry, including E&S, Silicon Graphics, Adobe, Ashlar, Atari, Pixel Planes, Netscape, Pixar, etc.

The Utah program later evolved into the *Geometric Design and Computation group* (GDC), established by Rich Riesenfeld and Elaine Cohen. The GDC was engaged in both fundamental and applied research in developing methods for representing, specifying, manipulating, and visualizing geometric models. The group had projects ranging from early conceptual design methods to innovative manufacturing processes and from detail modeling applications to large-scale assembly systems. Supporting these applications was fundamental work on surface and model representation, computational geometry, topology, differential geometry, and numerical methods.

One of the early premiere GDC efforts was the Alpha_1 modeling environment. Based on GDC project research results, the Alpha_1 system was an advanced research software base, supporting use and research in geometric modeling, high-quality graphics, curve and surface representations and algorithms, engineering design, analysis, visualization, process planning, and computer-integrated manufacturing.

Solid models in Alpha_1 were represented by trimmed B-spline (NURBS) sculptured-surface boundary representations. That is, the surfaces of a solid were represented explicitly, and linked together by shared edges.

It was implemented in C++, and provided both command-language and graphical, menu-driven interfaces. Much of the heart of the geometry was based on the pioneering spline work of Riesenfeld (Syracuse University) and the subdivision work of Riesenfeld, Cohen and others.



More about Alpha_1 can be found at

*http://www.cs.utah.edu/gdc/projects/alpha1/*

# 4.5 The Ohio State University

*Charles Csuri*, an artist at The Ohio State University, started experimenting with the application of computer graphics to art in 1963. (See *Art, Computers and Mathematics*, by **Charles Csuri** and James Shaffer, AFIPS Conference Proceedings, V33, FJCC, 1968). His efforts resulted in a prominent CG research laboratory that received funding from the National Science Foundation and other government and private agencies. The work at OSU revolved around animation languages, complex modeling environments, user-centric interfaces, human and creature motion descriptions, and other areas of interest to the discipline.

Working as a painter, Csuri[1] became increasingly fascinated with the computer and its potential as an artistic tool. His early "computer" work involved the creation of an analogue device to process images, much like a pantograph traces an image. By changing the length of one or more components, the image could be redrawn in a transformed state. In a pointed commentary on the state of the technology at the time he created an image of a devil holding a punch input data card.

After Albrecht Dürer (1964)

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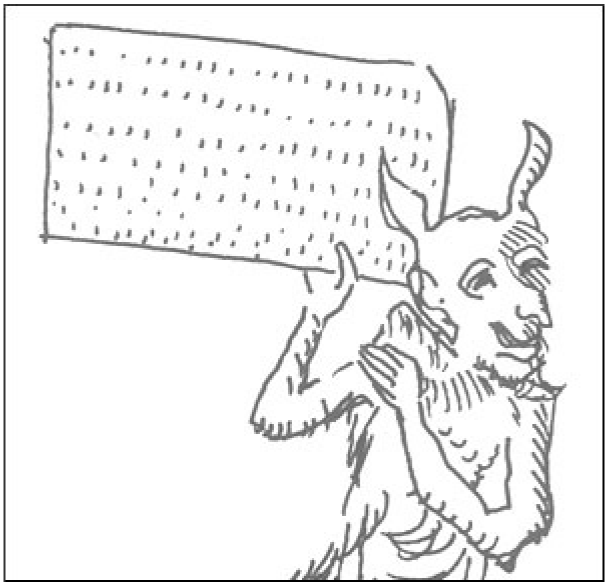
[1] Csuri was featured in a 1995 cover article of the Smithsonian magazine, written by Paul Trachtman and titled "Charles Csuri is an 'Old Master' in a New Medium".



Devil with Punch Card (1964)

In 1967, he used a line drawing of a man, and working with a fellow faculty member (James Shaffer) from the Department of Mathematics, modified its shape using a sine curve mapping and a mainframe computer (IBM 360). Lacking an output medium for recording this primitive animation, he plotted the intermediate frames on paper using an IBM plotter to create a haunting blend of images (called Sine Curve Man).

*Sine Curve Man (1967)*

That same year, he continued with this experimentation on other drawings, including one of a *hummingbird* in flight. Csuri produced over 14,000 frames, which exploded the bird, scattered it about, and reconstructed it. These frames were output to 16mm film, and the resulting film Hummingbird was purchased by the Museum of Modern Art in 1968 for its permanent collection as representative of one of the first computer animated artworks.

*Hummingbird (1968)*

Also in 1968, Csuri was one of the featured artists at an exhibition at the Institute of Contemporary Arts in London, and his work in computer animation was featured in the catalogue titled "*Cybernetic Serendipity – the computer and the arts*," published that year by Studio International. This publication was the one of the first collections that dealt with "…the relationships between technology and creativity."

*View of the Cybernetic Serendipity exhibition in 1968. Csuri's art can be seen on the black board in the center of the photo.*

*Numeric Milling (1968)*

At the end of the decade, Csuri was also experimenting with many different kinds of output media, collaborating with mathematicians and scientists. One of his partners created a “tool” for defining a mathematical surface (what became known as the Fergusen patch) that Csuri then had sculpted in wood on an Engineering Department milling machine.

Csuri continued to work with graduate students and fellow faculty members from the arts and sciences for the next several years, experimenting with different approaches to instructing the computer to display and animate the various artifacts that he conceived. In 1969 he received a prestigious grant from the National Science Foundation to study the role of the computer and software for research and education in the visual arts. This was very unusual, for an artist to receive an NSF grant, and showed the level of significance of the work at OSU at the time. (In fact, an internal report done at the National Science Foundation stated that the greatest impact on the field of computer animation could in part be attributed to the work at the Computer Graphics Research Group at Ohio State.)[2]. Additional images from Csuri can be seen below in Gallery 4.1.

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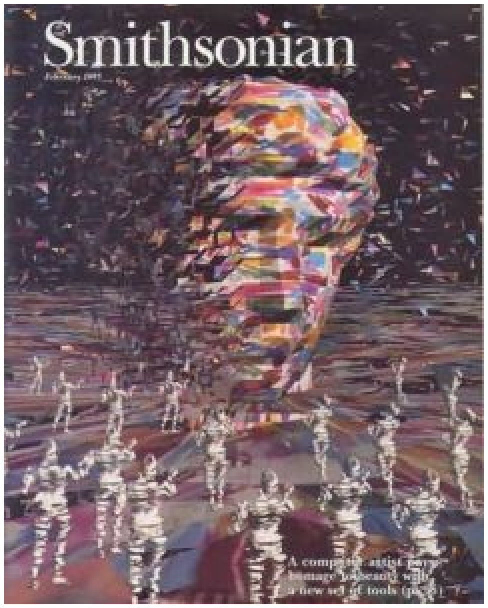
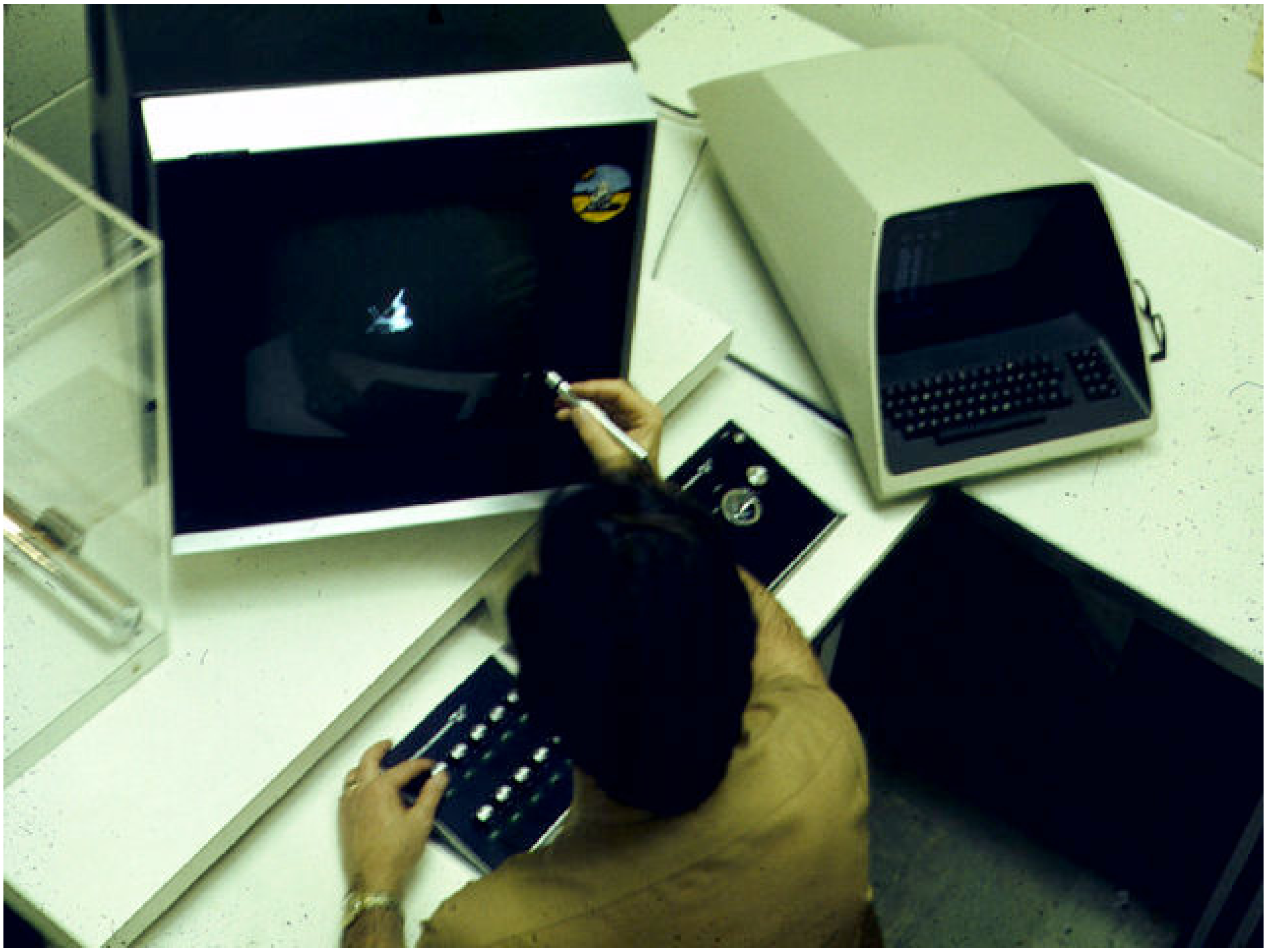
[2] Csuri was featured in a series of prestigious retrospective exhibitions of his work. The SIGGRAPH professional graphics organization hosted an exhibition of his work titled "Beyond Boundaries, 1963-present" in 2006 in Boston. This exhibition also traveled to the Kaohsiung Museum of Fine Arts in Taiwan in 2008, to several venues in Europe, and to the Urban Arts Space in Columbus, Ohio in 2010.



*Csuri, featured in Smithsonian Magazine*

In 1971 he proposed a formal organization, called the Computer Graphics Research Group (CGRG) in order to realize the potential of the application of computer animation to the studies by students in the Art Department, and to have a formal cohort that could attract external research support. Members of CGRG included faculty and graduate students from Art, Industrial Design, Photography and Cinema, Computer and Information Science, and Mathematics. Grant proposals were submitted to agencies and programs both in and out of the University, and funding was provided for studies that would extend the capabilities of the evolving discipline. The group was housed in space in the OSU Research Center at 1314 Kinnear Road on the OSU campus. Equipment in the lab at this time included a 32K IBM 1130 computer interfaced to an IBM 2250 Model IV graphics display, and the FORTRAN programming language was used as the primary programming environment.

Research and development work conducted by CGRG members during this early period included hidden line and visible surface algorithms, linear interpolation, path following, data smoothing, shading and light source and reflection control, compound transformations, 2D and 3D data generation and sophisticated interaction techniques. This seminal work evolved into a general interest in dynamic systems and languages for applications in computer-controlled display and motion. In 1970, Csuri published one of the first papers related to the complex issue of animating objects in real time.



*Chuck Csuri working with light pen attached to a Vector General vector graphics display*

*CGRG's DEC PDP-11/45 computer*

Csuri was awarded his second NSF grant in 1971 for a project titled "*Software and Hardware Requirements for Real Time Film Animation*." The University provided matching equipment support, and the CGRG installed a 48K word PDP-11/45 computer and a Vector General graphics display with 3D hardware transformation capabilities in 1972. This grant supported Computer Science graduate students Tom DeFanti, who developed the animation language Graphics Symbiosis System (GRASS) in 1972, and Manfred Knemeyer, who developed the ANIMA system in 1973 for defining computer generated motion, using an integrated programming language. (Staff member Gerard Moersdorf helped write a large amount of the GRASS code.) Both of these systems were designed with traits that DeFanti, who went to the EVL at the University of Illinois, called *habitability* (ease of use by novices) and *extensibility* (the use of stored files to be interpreted by the system), and both linked to external controls like dials, buttons and joysticks in addition to command line control.

Expanding on Csuri's early work in blending of line drawing images, Mark Gillenson developed a system (WhatsIsFace) that used techniques of key frame animation to blend images to create facial drawings, a system that created a significant amount of interest in the police and investigative communities. This system was one of the first formal contributions to the technology that is now called "**morphing**".

CGRG efforts embraced a fundamental philosophy that these complex computer animation capabilities could be made available on microcomputers (eg, PDP 11/45) and could be easy to use. The group continued to receive NSF and other internal and external support for this effort, and published extensively during the early 1970s on animation and animation control as well as human-computer interfaces. The University expanded their support and funded additional equipment (another Vector General display, a computer-controlled camera system, and a communications link with the University's PDP-10 mainframe.) In 1975, Csuri contracted with John Staudhammer of *NC State* (through his company Digitech) to build a special "run-length encoding" storage and display device that allowed CGRG to move from a strictly vector display environment to raster and color graphics.

Richard Parent joined CGRG in 1974 to develop geometric modeling tools for animation (his 1977 dissertation received the "Best PhD Dissertation Award" from the National Computer Conference). During this early period, Alan Myers studied and developed **rendering** algorithms (coded in the PDP 11 assembly language) that could run efficiently in the minicomputer environment to make high quality imagery.

Ron Hackathorn worked to expand Knemeyer's Anima animation system, and Tim Van Hook brought a user perspective to the design, as well as a knowledge of real time issues.

**Movie 4.13** Pong Man

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/pongman_77.m4v

*Pong Man was created by Tim VanHook to demonstrate the use of Anima II to produce creature motion.*

The development activities resulted in the ANIMA II animation system, which supported procedural modeling and run-length encoding algorithms, the DG modeling system for data generation, and other supporting systems and languages. The group expanded to include Rodger Wilson and Wayne Carlson, and a number of other graduate students from various departments during this period.

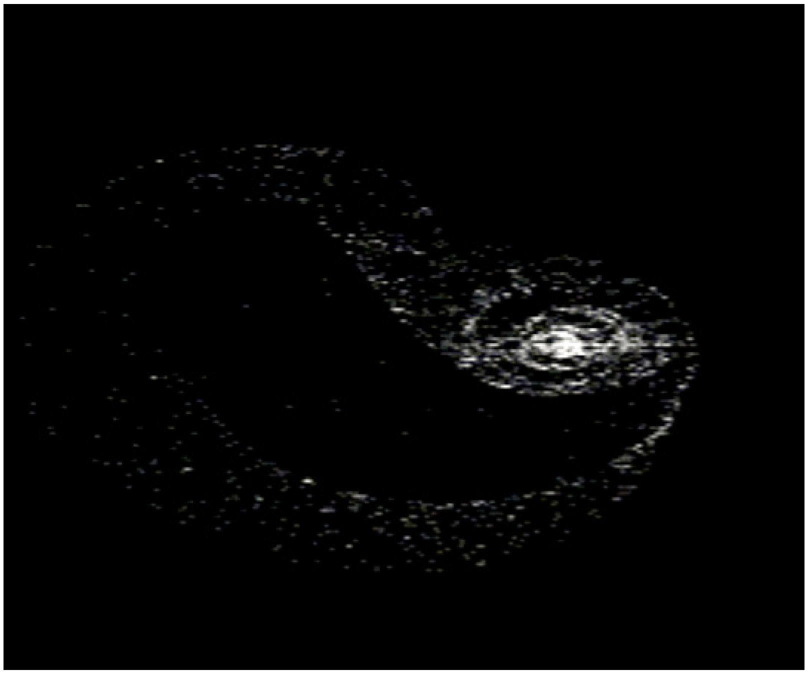
*8-legged articulated mobile robot*

Early investigations into "creature" animation were both influenced by and supported the work of OSU Prof. Robert McGee and his 8-legged articulated mobile robot designed and built at Ohio State.

CGRG team members used the systems that were developed in the lab to generate computer animations that were shown throughout the mid to late 1970s, and published the results of their work in SIGGRAPH proceedings and other journals. The group was also featured in many popular media presentations, including television features such as PM Magazine and the national CBS Sunday Morning with Charles Osgood.

Charles Osgood, host of CBS Sunday Morning, featuring CGRG

Important work produced during this period included a visualization of interacting galaxies, which was shown on the Carl Sagan Cosmos series, by Bob Reynolds (it was updated with a complex **particle system** in 1978 by Wayne Carlson), studies of time in virtual environments, the use of CGI in visualizing statistical data, the use of animated sequences to help teach language constructs to deaf children, terrain modeling and harbor pilot training simulation, and computer art. CGRG created one of the first 3D computer generated animations used for a television station, the CBS affiliate WBNS-TV in Columbus, Ohio in 1978.



Interacting Galaxies

Frame from WBNS animation

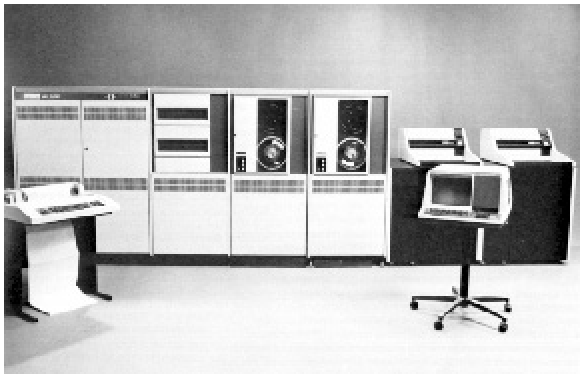
Funding for the research at CGRG was provided by the University, the National Science Foundation, the Naval Weapons Training Center, the Air Force Office of Scientific Research, and the U.S. Department of Education. Carlson and Rick Parent were also part of a consulting team to Boeing to conduct a major graphical user interface study for the Air Force ICAM (Integrated Computer Aided Manufacturing) program.

In the late 1970s, the focus of the work turned in the direction of increased complexity of modeling and animation and visual accuracy. Ron Hackathorn and Rick Parent developed the next generation animation system, called ANTSS, which was one of the first systems that combined motion specification and rendering in the same system.

As mentioned earlier, Parent received his PhD degree in 1977, which focused on a modeling system called DG, which was likened to a tool for sculpting clay in the computer environment. Parent was appointed the Associate Director of the lab after his graduation.

Wayne Carlson worked with Rodger Wilson and Bob Marshall to expand the procedural animation capabilities introduced by Martin Newell of the University of Utah, and also developed an expanded surface modeling environment that used higher order curves and surfaces, such as Bezier and b-splines, as part of his PhD research. Carlson also investigated ??points as a display primitive that could be used to efficiently compute and display “fuzzy” objects, i.e. those with no “solid” 3-D structure (eg, smoke, fire, water, etc.) He applied this research to generate an image of a smokestack, and he recalculated the interacting galaxies sequences first produced by Reynolds, increasing the geometry from several hundred geometric primitives (stars) to over 30,000 in each galaxy.

Carlson’s DG2 system expanded the modeling work of Rick Parent, and was a system for modeling geometry that included points as a geometric primitive (what would later become known as **particle systems**), boolean operators on surface patches, and a unified approach to sweep operators. CGRG images from this period can be seen in Gallery 4.2 below.



DEC VAX 11/780

Frank Crow, a PhD student of Ivan Sutherland at Utah,was recruited from the University of Texas and worked with approaches to increased scene description and rendering capabilities and continued his work with shadows and antialiasing that were started at the University of Utah. At CGRG he investigated multi-processing approaches to image synthesis and other algorithmic solutions for complex images. He later went to Xerox PARC, Apple Computer, Interval Research, and then to NVIDIA.

During Crow’s tenure at OSU, the PDP-11/45 was replaced with one of the earliest VAX 11/780 models on the market, and the FORTRAN and assembly language code was translated to the C language in the Unix environment.

Dave Zeltzer developed goal-directed motion description capabilities for skeletal and creature animation (the *Skeletal Animation System – SAS*). His system and the underlying theories are some of the most significant contributions to the area of autonomous legged motion description in the discipline.

Don Stredney (the Ohio Supercomputer Center) pushed the limits of the modeling systems of Carlson and Parent to develop complex anatomical models, including the skeleton”George” used by Zeltzer in his research. George became a graphics “cult” figure, and the geometric model was distributed widely throughout the field.

Mark Howard moved from Staudhammer’s NC State program and designed and built a controllable 512×512 frame buffer that allowed real-time playback of animation tests. This frame buffer and later versions of the design were the mainstay of the image creation and representation capabilities at CGRG and later at Cranston/Csuri Productions.

Julian Gomez developed TWIXT, a track-based **keyframe** animation system. This system allowed for the specification of key-framed motion for independent objects that moved over the same time interval. It had real time playback, with shape morphing, and was device independent.

Other important work done during this period included films *Snoot and Muttly* by Susan Van Baerle and Doug Kingsbury, *Trash* by John Donkin, *Tuber's Two-Step* by Academy award winner Chris Wedge, *Vision Obious* by Ruedy Leeman, early character animation by Michael Girard and George Karl, and animations by Susan Amkraut, Marsha McDevitt, Thuy Tran, Kevin Reagh, Anne Seidman, Tom Hutchinson, Bill Sadler and others. CGRG images from this period can be seen in Gallery 4.3 below.

CGRG continued to advance, concurrently with the efforts at Cranston/Csuri Productions (see Chapter 6) across the lobby in the 1501 Neil Avenue building. In 1987 Tom Linehan and Chuck Csuri oversaw the conversion of the Computer Graphics Research Group into *The Advanced Computing Center for the Arts and Design*, with funding from a long-term Ohio Board of Regents Academic Challenge grant. ACCAD was established to provide computer animation resources in teaching, research and production for all departments in the College of the Arts at Ohio State.

**Movie 4.14** Dawn of an Epoch

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/epochd-1.m4v

*Video of CGRG and ACCAD's role in the advancement of computer graphics and animation as it becomes a widely used scientific tool.*

During this period, significant research and production was done in the area of animation by many faculty, staff and students, including Joan Staveley, James Hahn (rigid dynamics), David Haumann (flexible dynamics), Chris Wedge, Brian Guenter (parallel graphics), Doug Roble (compositing), Paul MacDougal (levels of detail), Scott Whitman (Parallel algorithms), Beth Hofer (facial animation), Susan Amkraut and Michael Girard (flocking and human locomotion), Midori Kitagawa (Boolean operations), John Chadwick (layered skeleton control of human motion), David Ebert (procedural animation), Jim Kent (3D object morphing), Rob Rosenblum (rendering and animation of hair), and Ferdie Scheepers (animation and modeling of human musculature). The building housing ACCAD (and C/CP) can be seen in the Movie 4.14 as well as in Gallery 4.4 below.

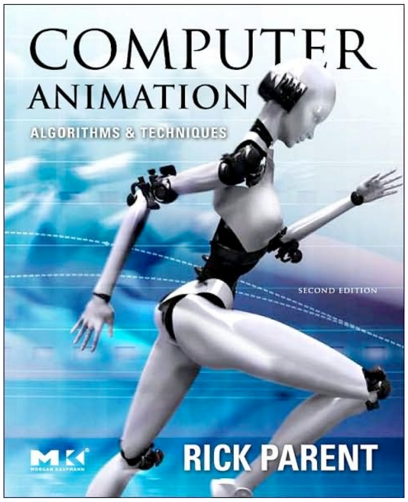
There were also many arts and design students who were involved in award-winning computer animations, and who are now very important educators or animators for the industry. A list of the alumni of the program and their affiliations can be found at the ACCAD web site at

*http://accad.osu.edu/people/alumni.html*

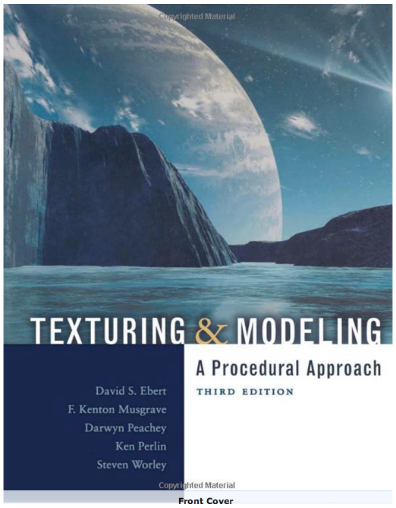
ACCAD was established as an interdisciplinary research center, and was instrumental in many research investigations around computer graphics, animation, visualization, multimedia, etc. A partial listing of the projects and funding can be found on the research section of their website at http://accad.osu.edu/researchmain/gallery/most-recent.html

Wayne Carlson became the Director of ACCAD in 1991 after Csuri retired. In 2000, Maria Palazzi returned to Ohio State as Associate Director, and in 2001 assumed the Directorship when Carlson became the Chair of the Department of Design at OSU.

In 1985 Rick Parent started the CG Lab in the Department of Computer Science in the College of Engineering at OSU. He was later joined by Wayne Carlson, Roni Yagel, Ed Tripp, Kikuo Fujimura, Roger Crafis, and others. Early focus of the lab was on computer animation, particularly character motion, procedural effects, visualization, and geometric modeling. Parent wrote the definitive textbook on computer animation, *Computer Animation, Algorithms and Techniques*, and graduate David Ebert edited the book *Texturing and Modeling*.



Parent book



Ebert book

Several influential graduate students came through the CG Lab, some working specifically in the lab, and others also working through ACCAD. For example, Doug Roble won an Academy Award for his work at Digital Domain on motion tracking software; Michael Girard started his own company in 1993, Unreal Pictures, that created the animation software Character Studio, later purchased by Discreet; Dave Haumann was the lead technical director on the 1997 Academy Award winning Geri’s Game; Steve May became the Chief Technology Officer for Pixar.

Graduates of the CS program work in many corners of the computer graphics industry, as technical directors in most major production companies, in the game industry, at NVIDIA, Adobe, Sony and other companies, as well as teaching in some of the top universities in the country. More information can be found at the CG Lab web site.

Chris Yessios started on the faculty at Ohio State after receiving his graduate degree in 1973 from Charles Eastman’s Computational Design Lab at Carnegie-Mellon University, where he became interested in the applications of CAD to architecture. He and his students in the School of Architecture started looking at how this evolving field could be used to impact the way CG and CAD could be used in the design process. At the time, the university was using 2D drafting and 3D modeling programs running on mainframes. Frustrations with the cost of these large computers and some of the emerging turnkey CAD workstations changed when the early Macs became available. They started developing software that would run on the personal computer and provide sophisticated 3D capabilities.

Images source: form·Z Joint Study Journal

In 1990, Yessios and a former student David Kropp, founded AutoDesSys (standing for Automated Design Systems), and developed the popular 3D modeling software, form•Z. They also developed the software products RenderZone and Bonzai3D. The AutoDesSys software was designed to be used in architecture, product design, interior design and illustration applications.

**Movie 4.15** Form•Z 2007 User Reel

https://www.youtube.com/watch?v=3PewiPQdA5g

**Some Early CGRG and ACCAD videos**

**Movie 4.16** *Hummingbird* (1966)

**Movie 4.17** *Rigid Body Dynamics* (Hahn 1989)

**Movie 4.18** *PM Magazine*

**Movie 4.19** *Interacting Galaxies* (Reynolds 1977)

**Movie 4.20** *Anima II*

**Movie 4.21** *The Circus*

**Movie 4.22** *Procedural Terrain Models*

**Movie 4.23** *Snoot and Muttly* (Van Baerle / Kingsbury 1984)

**Movie 4.24** Broken Heart (Staveley – 1988)
*http://www.youtube.com/watch?v=iPLFB6_xpAI*

**Movie 4.25** *Tuber's Two Step* (Wedge – 1985)

**Movie 4.26** *Zeltzer SAS V1*

**Movie 4.27** *Girard/Karl Creature Motion Studies (1985)*

**Movie 4.28** *Eurythmy* (Girard and Amkraut – 1989)

**Movie 4.29** *Coredump* (1989)

**Movie 4.30** *Tectonic Evolution* (1995)

*Art, Computers and Mathematics*, by Charles Csuri and James Shaffer, AFIPS Conference Proceedings, V33, FJCC, 1968

Csuri, Charles. *Computer Animation*. Proceedings of SIGGRAPH 75.

Csuri, Charles. Real Time Film Animation, 9th Annual UAIDE Proceedings, 1970.

Rick Parent, *A System for Sculpting 3D Data*, Proceedings of SIGGRAPH 77.

Ron Hackathorn, *Anima II – A 3D Animation System*, Proceedings of SIGGRAPH 77.

Wayne Carlson, Robert Marshall, and Rodger Wilson. "*Procedure Models for Generating Three Dimensional Terrain*," Computer Graphics, V14, #2, July, 1980, pp. 154-161.

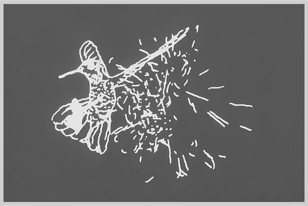
C. Csuri, R. Hackathorn, R. Parent, W. Carlson, M. Howard. "*Towards an Interactive High Visual Complexity Animation System*," Computer Graphics, V13, #2, August, 1979, pp. 289-299.

*Ohio State Pioneers Computer Animation:Making Birds Fly and Babies Walk*. Computer Graphics World article about CGRG by Tom Linehan, October 1985

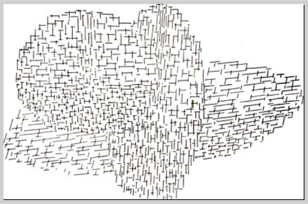
Csuri, Charles. *Art and Animation*, IEEE Computer Graphics and Applications, January 1991

**Gallery 4.1** Other Csuri Artwork

Chuck Csuri at CGRG (1978)

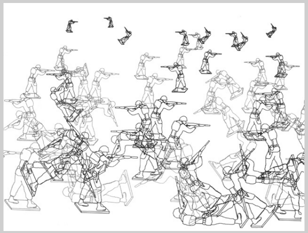


Scene from Hummingbird



After Mondrian

Shaded Man



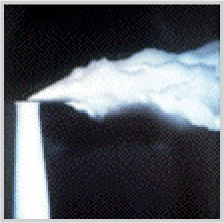
Random War

**Gallery 4.2** Early CGRG Imagery

Fall Tree, made with Procedural Modeling

Summer Tree

Forest of Trees



Particle System Smoke Cloud

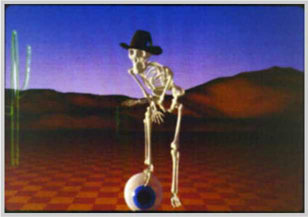
Patch Intersection Algorihtm

**Gallery 4.3** Other CGRG Imagery

Data made with DG2

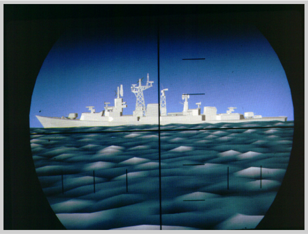
Scene from a movie by Frank Crow showing capabilities of the scn_assmblr animation control system.

Scene from Snoot and Muttly by Kingsbury and Van Baerle

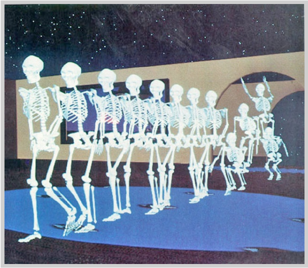


“George in the Desert” – data created by Don Stredney on DG2

Image from paper by Jim Kent – 3D interpolation



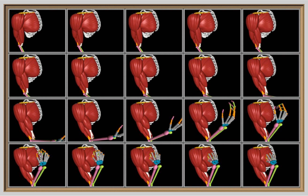
Scene from Norfolk ship pilot simulator.



Scene composite from Zeltzer SAS system

**Gallery 4.4** CGRG/ACCAD Imagery

Scenes from “Butterflies in the Rain”



Stills from muscle simulation – Ferdie Scheepers and Steve May

Cranston Building, home of CCP and CGRG

CCP lobby

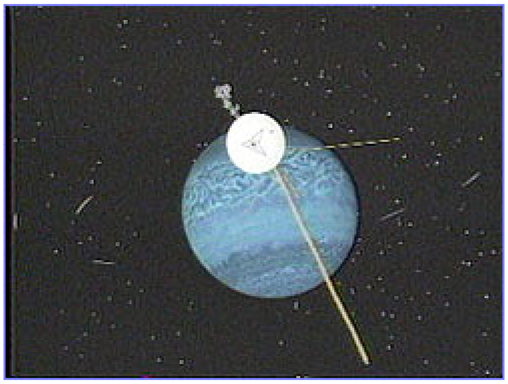
# 4.6 JPL and National Research Council of Canada

## Jet Propulsion Lab (JPL)

*Jim Blinn*

Bob Holzman established the JPL CG Lab at the Jet Propulsion Lab in 1977. Working with Ivan Sutherland, who had moved from the University of Utah to Cal Tech, Holzman envisioned a group with technology expertise for the purpose of visualizing data being returned from NASA missions. Sutherland recommended a graduate student at Utah named **Jim Blinn**, whose name has become synonymous with JPL and with graphics in general. (Sutherland once allegedly commented that "There are about a dozen really great computer graphics people, and Jim Blinn is six of them.") Several other notable graphics people worked at JPL, including Alvy Ray Smith, Pat Cole, and Julian Gomez.

Blinn received his bachelor's degree in physics and communications science from the University of Michigan in 1970, before computer science was offered as a college subject. He went on to earn a master's degree in engineering at Michigan and a Ph.D. in computer science at the University of Utah in 1977. In 1976 Blinn engaged in an internship at NYIT, where he worked with former classmates, including Ed Catmull, on pressing issues in computer graphics.



*Voyager spacecraft*

*Saturn, as seen from Voyager*

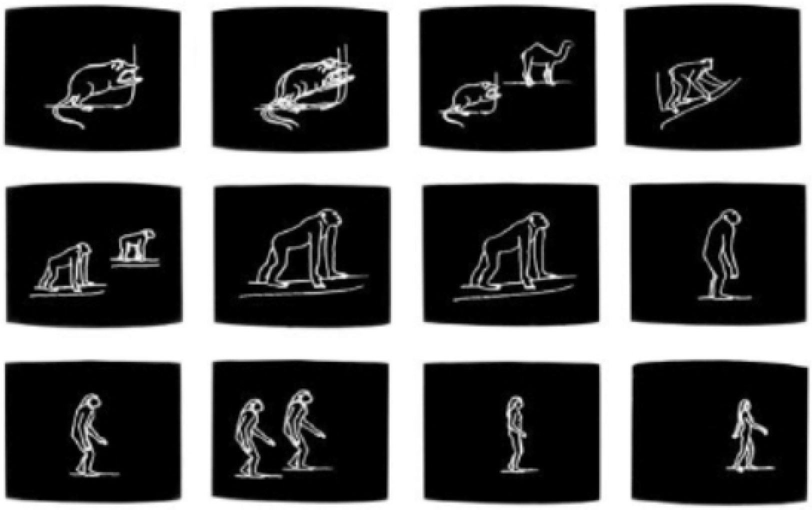
Blinn had worked with a wide range of imaging techniques while at Utah, including the design of a comprehensive paint program called *crayon*, and had the vision to develop these techniques into a viable system for the visualization task that Bob Holzman outlined. He arrived at JPL right after the Voyager spacecraft had left for a space review of the outer planets. When he showed up for work at JPL, he was introduced to the work of Voyager Mission Design Manager Charles Kohlhase's work, including an animated line drawing of the Voyager fly-bys. Although it wasn't an official NASA project, Blinn  and other JPL staff, including Kohlhase and Pat Cole, produced a series of realistic raster"fly-by" simulations, including the Voyager, Pioneer and Galileo spacecraft fly-bys of Jupiter, Saturn and their moons.

It was stated in an interview with Blinn at fxguide.com that he originally used the actual mission planning data to define the path of the spacecraft, and used textures from his paint program to depict surface characteristics. He later replaced them with actual images returned from the spacecrafts. Two of his colleagues from NYIT, Alvy Ray Smith and David Difrancesco helped with responding to NASA requests for a high quality version of his animations, with Smith organizing the camera moves. These animations were so realistic, they became part of the NASA press-kit, and were sometimes interpreted by the public as real movies returned from space.

*Kohlhase, Blinn and Cole*

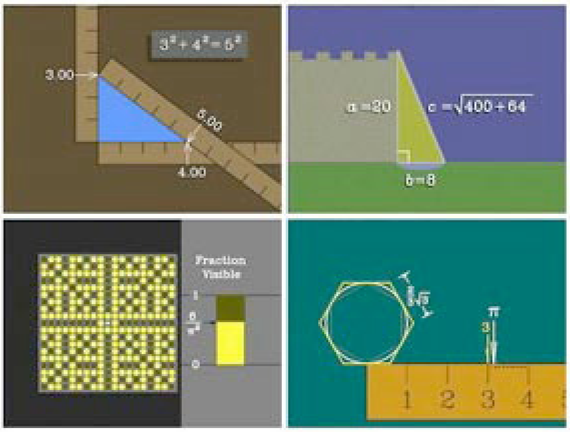
Next, Blinn worked with Carl Sagan on the PBS *Cosmos* series, a 13-part series produced by KCET in Los Angeles. The series was based on Sagan's book *Cosmos: A Personal Journey*, and the value-added was the CG effects from Blinn, and the series won both the Emmy and Peabody awards.

Blinn developed CG sequences for an Annenberg/CPB series, *The Mechanical Universe*, which consisted of over 500 scenes for 52 half hour programs describing physics and mathematics concepts for college students. The real success of this effort was in the explanation of complex science to the general public. In order to produce the detailed CG for these images, he developed new techniques for cloud simulation and a modeling technique variously called metaballs, or what he called "blobby objects."



*Scenes from Cosmos*

Due to the overwhelming reception of the imagery produced for *The Mechanical Universe*, in 1989 Blinn began production of another series devoted to advanced mathematical concepts. Originally titled Mathematica, the title had to be changed because of a software program called Mathematica for mathematics simulation. The series title was changed to *Project Mathematics!* and was produced largely at CalTech.



*Scenes from Project Mathematics!*

Holzman, in an *article in 1986 for the Visual Computer*, talked about the hardware environment at JPL:

The hardware system is regular ‘off the shelf’ components assembled to fit NASA’s budget and needs.

The Computer Graphics Lab timeshares on a cluster of two Vax 8600s, two Vax 11/780s, and two Vax 11/750s. One of the Vax 11/780s is allocated for priority processing and the other machines are available for low priority computing during low demand time periods.

A vector display is used as a tool for designing the objects within a scene, and for designing and studying the animation action. Because of its ability to draw 40,000 vectors per second, the vector display is used for previewing action in real time. The third component in the hardware system is the frame buffer (raster display device) with a resolution of 486 lines and 512 samples of 24 bits each. The device is compatible with video resolution and allows for the use of 16,777,216 colors for full color images. The raster device is used for viewing a fully rendered image on the color monitors and for recording 1″ video tape. (The video equipment came with The Mechanical Universe Project in 1983. Previous animations were made to 16 mm film.)

In 1981 Blinn and Pat Cole left JPL to work at Industrial Light and Magic, but the lure of space visual simulation brought him back to JPL. He later went to Cal Tech, and then Microsoft, where he was involved with the Direct3D project. He received the SIGGRAPH Computer Graphics Achievement Award in 1983, the NASA Exceptional Service Medal for his work on the planetary flyby animations produced at JPL. and the prestigious MacArthur Foundation Fellowship in 1991, and the Coons award from ACM-SIGGRAPH in 1999.

In 1998, Blinn gave the keynote address to the SIGGRAPH 98 Conference in Orlando Florida. In his speech, he reviewed the 25 previous conferences, outlined a number of “unsolved problem” designations, and gave his own accounting of the ten unsolved problems in CG. A slide summary of his address is on the SIGGRAPH 98 website at *http://www.siggraph.org/s98/conference/keynote/blinn.html*

**Movie 4.31** *Mechanical Universe*

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/mechanical-2.m4v

*This film by Jim Blinn features the animation from The Mechanical Universe. The opening frames are representative of his early work with the spacecraft fly-by animations.*

**Other JPL Movies**

**Movie 4.32** *L.A. The Movie (1987)*
and
**Movie 4.33** *Mars The Movie (1989)*

**Other animations by Jim Blinn**

**Movie 4.34** Voyager 2 Flyby of Saturn (1981)
https://www.youtube.com/watch?v=SQk7AFe13CY

**Movie 4.35** Evolution (1980) – from Cosmos
https://www.youtube.com/watch?v=YEdm1GoUo-o

**Movie 4.36** Pioneer 11 Encounters Saturn (1980)
https://www.youtube.com/watch?v=myYIKJF589g

**Movie 4.37** Voyager 2 Encounters Jupiter (1978)
https://www.youtube.com/watch?v=o4xIJlEV8Kw

**Movie 4.38** Project Mathematics! (1988)
https://www.youtube.com/watch?v=PslowEd4-68

**Movie 4.39** Voyager 2 Flyby of Uranus (1986)
https://www.youtube.com/watch?v=DrKQaDupdWQ

**Movie 4.40** Computer Visions feature on Jim Blinn (1991)
https://www.youtube.com/watch?v=ePZ301Sg4HI&t=6s

Blinn wrote a series for IEEE Computer Graphics and Applications (for which he received the IEEE Service Award), several books for Morgan Kaufman titled *Jim Blinn's Corner (eg, Ten More Unsolved Problems in Computer Graphics)*, and is the author of many influential papers, including:

*Texture and Reflection In Computer Generated Images*,
CACM, 19(10), October 1976, pp 542-547.
(The original teapot paper. Introduces environment mapping.)

*Models of Light Reflection for Computer Synthesized Pictures*,
SIGGRAPH 77, pp 192-198.
(Introduces the Torrance-Sparrow highlight model.)

*Simulation of Wrinkled Surfaces*,
SIGGRAPH 78, pp 286-292.
(Introduces Bump Mapping.)

*A Generalization of Algebraic Surface Drawing*,
ACM Transactions on Graphics, 1(3), July 1982, pp 235-256.
(Introduces Blobby Modeling.)

*Light Reflection Functions for the Simulation of Clouds and Dusty Surfaces*,
SIGGRAPH 82, pp 21-29.
(Lighting model for rings of Saturn.)

### National Research Council of Canada

National Research Council of Canada[1] scientist **Nestor Burtnyk** started Canada's first substantive computer graphics research project in the 1960s. **Marceli Wein**, who joined this same project in 1966, had been exposed to the potential of computer imaging while studying at McGill University. He teamed up with Burtnyk to pursue the promising field of applying evolving computer techniques to animation.

The Division of Radio and Electrical Engineering's Data Systems Group wanted to develop ways to make computers easier to use, and it settled on computer animation as the application to pursue after Burtnyk returned from a 1969 conference and heard an animator from Disney studios talk about how cartoons are made. In the traditional process, a head animator draws the key cels or pictures that demonstrate the actions. Assistants then draw the fill in pictures that carry the image from one key picture to the next.

The work of the artist's assistant seemed like the ideal demonstration vehicle for computer animation. Within a year, Burtnyk had programmed a complete "**key frame animation**" package that allowed the creation of animated

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[1] Portions of the text in this section were taken in part from a press release from the NRC announcing that Wein and Burtnyk were recognized as the "Fathers of Computer Animation Technology in Canada" by the Festival of Computer Animation in Toronto.

sequences by providing only the key frames. The National Film Board in Montreal was contacted, and a project to allow artists to experiment with computer animation was started.

The first experimental film involving freehand drawings, called *Metadata*, was made by artist and animator Peter Foldes. This led to a more substantial collaboration on a 10-minute feature called *Hunger/La Faim* about world hunger and about rich and poor countries.

It took Foldes and his NRC partners a year and a half to make, and in 1974 it became the first computer-animated movie to be nominated for an Academy Award as best short. It received other honors, including the Prix du Jury at the Cannes Film Festival and other international film awards.

**Movie 4.41** Excerpt from *Hunger/La Faim*

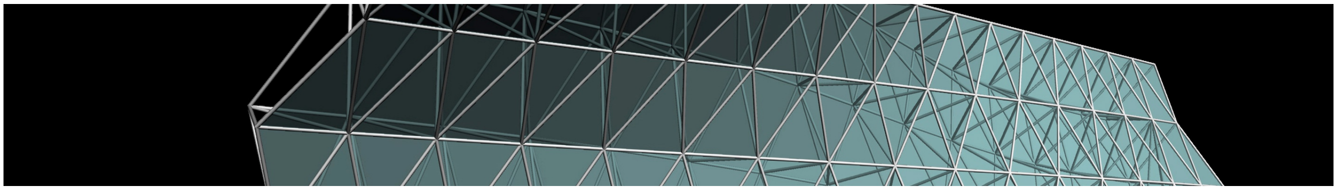
https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/hunger-excerpt.m4v

*Hunger, a film by Peter Foldes, can be seen in its entirety at http://www.youtube.com/watch?v=Vw5fi0iFBDo*

In 1996, Burtnyk and Wein received an Academy Award for Technical Achievement for their key-framing animation work.

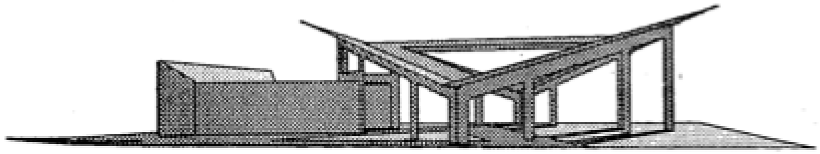
*Interactive Skeleton Techniques for Enhancing Motion Dynamics in Key Frame Animation* by Nestor Burtnyk and Marceli Wein in Communications of the ACM , October 1976, volume 19 #10, pp. 564-569

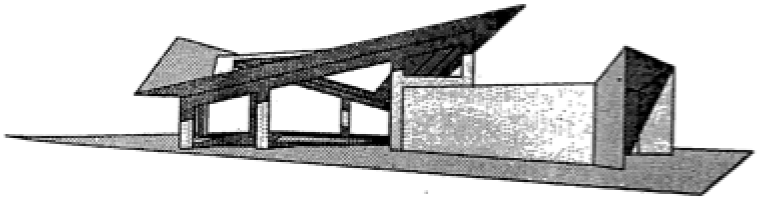
# 4.7 Other research efforts

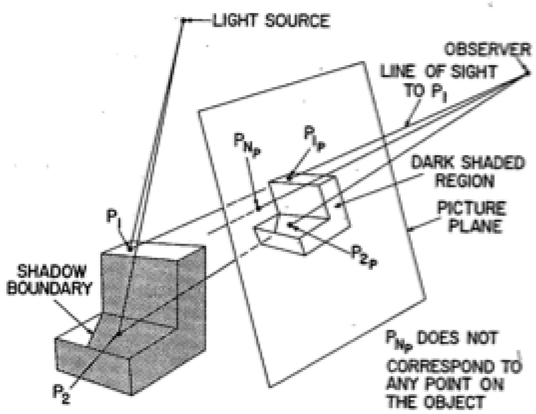


Of course, the discussions in the previous sections are not by any stretch of the imagination reflective of all of the research activities taking place in the U.S. or abroad during this early period. For example:

- Work in geometric modeling was being conducted at the Cambridge University CAD lab, with A. Robin Forrest and others. Forrest spent time at Harvard with Steven Coons, and developed a more stable approach to the representation of free-form curves and surfaces, that contributed significantly to CAGD development efforts;
- Arthur Appel and his team of researchers at IBM were developing software and hardware that would not only influence the future CAD industry, but that would affect the CG discipline at large. For example, he contributed to the rendering literature with his research into *hidden line solutions*; he provided what some claim to be the world's first exposure to ray tracing, with his process of determining whether a point was in shadow Images at right); and he introduced the concept of **quantitative invisibility** as an approach to visible surface determination;







- Automotive and aerospace companies, such as GM, Ford, Renault in France (**Pierre Bézier**), Boeing (Ferguson), McDonnell Douglas, and Lockheed Georgia (Chasen) were investigating software solutions for corralling the power of the digital computer for design activities. Chasen was a vocal proponent of the need for graphics hardware companies to develop better technology, and to leave the development of software components to the software industry groups that were much closer to the needs of the users;

Early computer graphics developments in Germany were initiated in Berlin by Wolfgang Giloi when he started there in 1965 in computer graphics GUIs, hardware and software R&D.Two of his former PhD students, Jose Encarnação and Wolfgang Straßer, made substantial contributions to key developments in computer graphics, like Z- buffer and raster technology, device-independent graphics and graphics standards.(See an accounting of this activity in an article on the *Giloi school.*)

Forrest, Archibald Robin.Curves and surfaces for computer-aided design. PhD dissertation, Published 1968 by University of Cambridge

Forrest, Robin. *The Emergence of NURBS*, IEEE Annals of the History of Computing, V20 #2, 1998.

Appel, Arthur. *Some techniques for shading machine renderings of solids*, Spring Joint Computer Conference, 1968 pp 37-45.

Appel, Arthur. *The notion of quantitative invisibility and the machine tendering of solids*, Proc. A.C.M. National Meeting, 1967 pp 387-393.

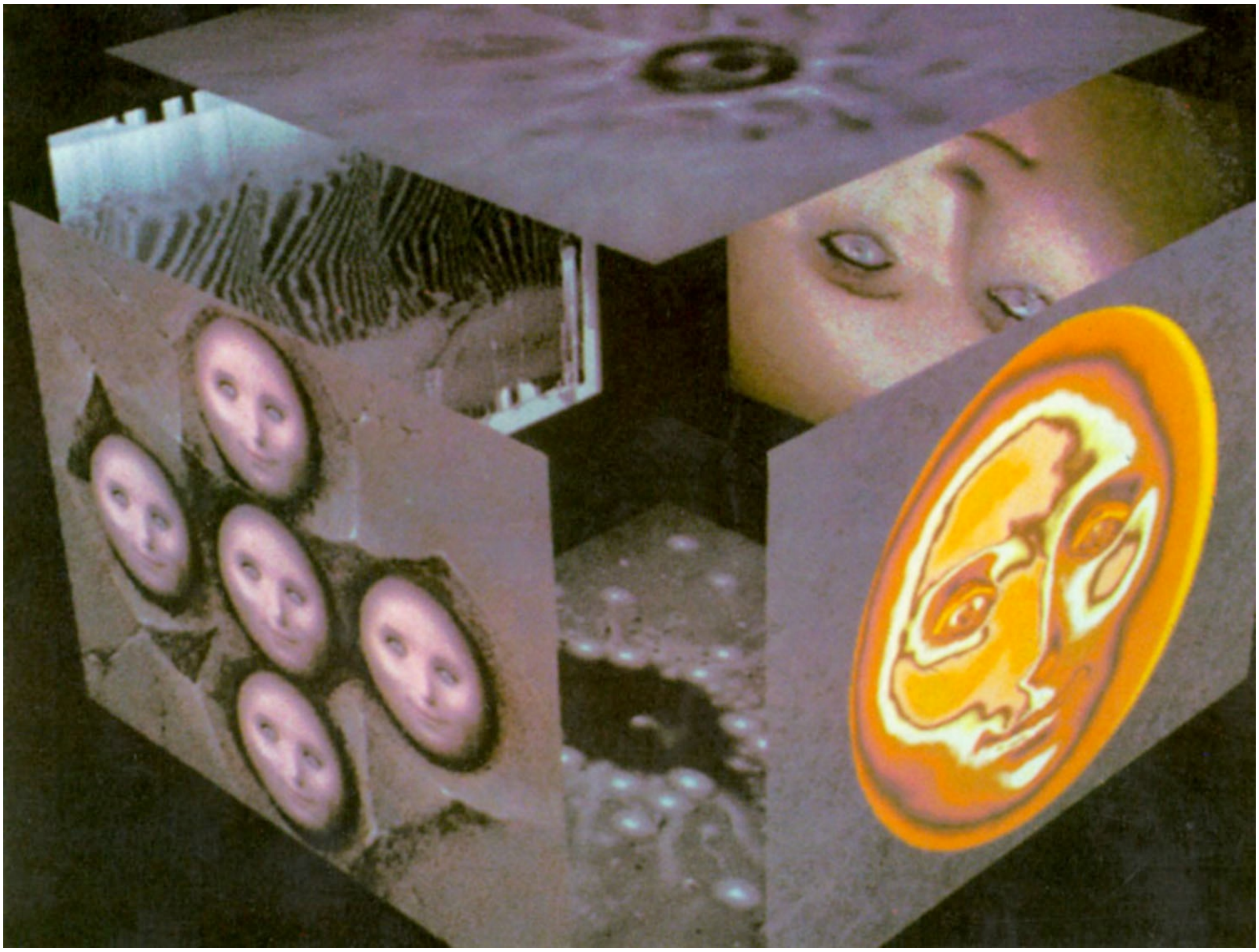
Appel, Arthur, F. James Rohlf and Arthur Stein. *The haloed line effect for hidden line elimination*, Proc. SIGGRAPH 79, pp151-157.

Giloi, Encarnacao and Strasser. *The "Giloi's School" of Computer Graphics.*

# Chapter 5: University research labs evolve

# University research labs evolve

The federal government and industries interested in the developing area of computer graphics saw the value of basic and applications research to obtain new solutions to problems that existed. Funding for these investigations became a priority, and universities around the world responded by supporting students and faculty. Dedicated laboratories were established, and academic programs grew out of these labs. Several of the early labs have already been discussed (Ohio State, University of Utah, Harvard and MIT). Several more can be considered instrumental in moving the discipline in the 1970s to an established industry beginning in the 1980s.



Sunstone, Emshwiller-NYIT (1979)

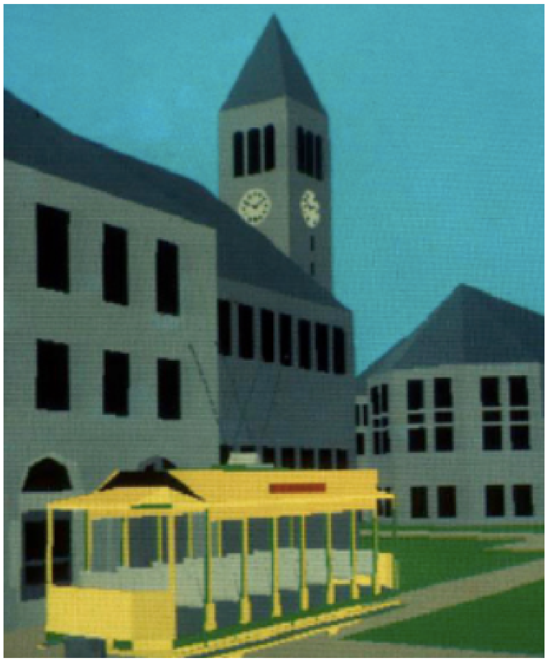
# 5.1 Cornell and NYIT

## Cornell University

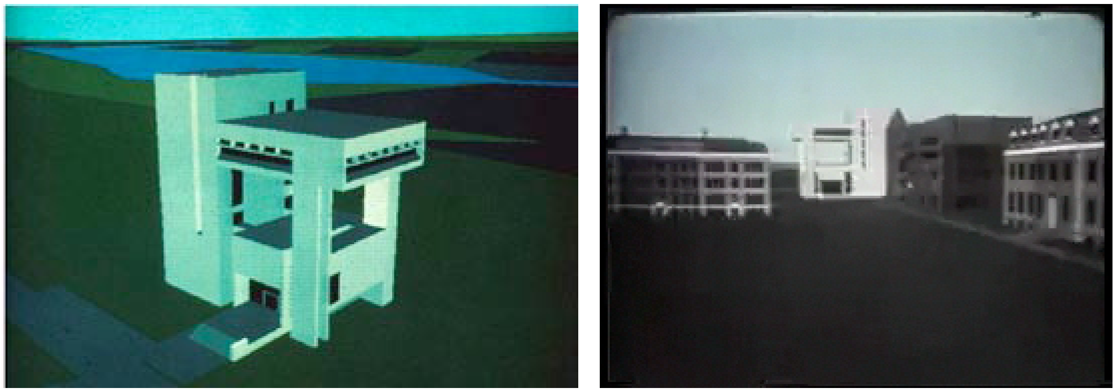
*Mosaic of Director Don Greenberg made up of images of former students.?A hi-res image can be seen at?* http://erich.realtimerendering.com/DPG/DPG.html

Cornell University, in Ithaca, New York, hosts one of the country's premiere laboratories contributing to the field of computer graphics imagery, the Program of Computer Graphics (PCG), founded in 1974 by the lab's director **Donald P. Greenberg**. The work of Greenberg and his staff and students forms the foundation for many of the practical applications that computer graphics experts and practitioners now routinely use.

Greenberg studied architecture and engineering at Cornell and also at Columbia University. He worked for Severud Associates, an architecture and engineering firm, and was involved with the engineering design of the St. Louis Arch, Madison Square Garden, and other projects.



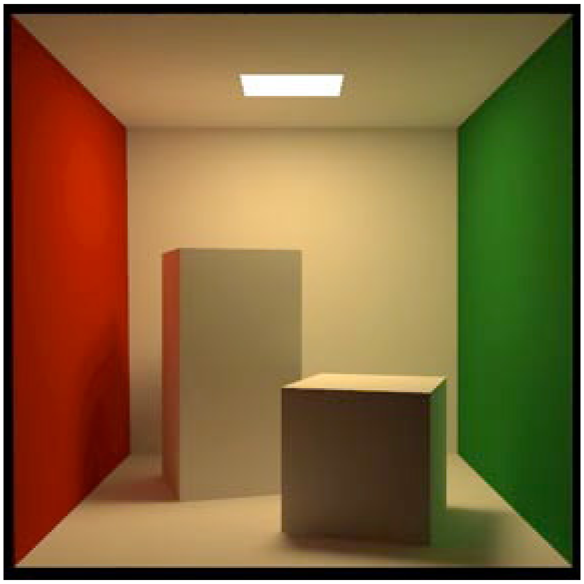
*Images from "Cornell in Perspective*



Like many of his contemporaries, the 1960s graphics pioneers in universities across the country, Greenberg saw how the complex engineering applications used by scientists could have an impact on the field of design and art. He received funding from the National Science Foundation to support the theoretical study and practical development of algorithms for the realistic display of images, particularly images of architectural environments.

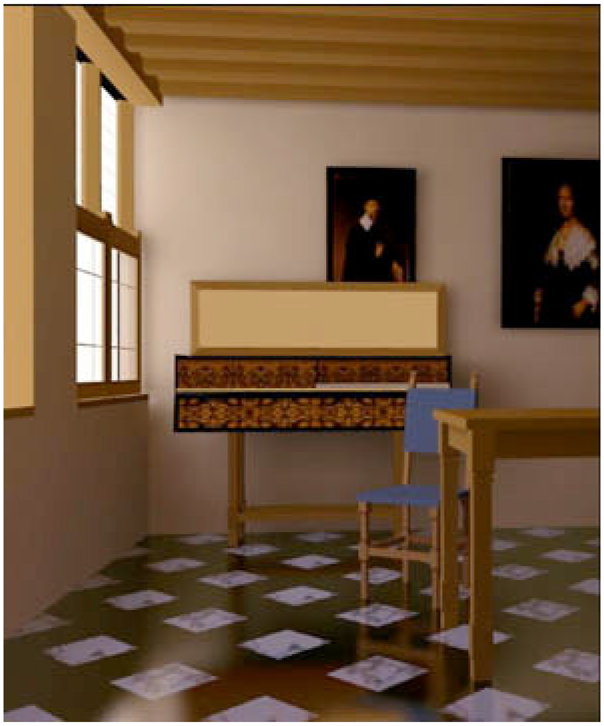
Prior to 1973, much of the research in computer graphics at Cornell was conducted at a General Electric research facility in Syracuse. Greenberg and his students would travel to Syracuse to arrive as the normal workday ended, and leave when the machines were needed by GE again the following morning.

The Program of Computer Graphics received its first National Science Foundation grant in the fall of 1973, which enabled Greenberg to order the lab's first computer graphics equipment. That equipment arrived early in January of 1974, and the first facility was set up in Rand Hall on the Cornell Campus. Greenberg published a *paper at SIGGRAPH 77* describing the Cornell Lab.



The Cornell Box

The Cornell PCG is best known for pioneering work on realistic image synthesis, including the **radiosity** method for calculating direct and indirect illumination in synthetic scenes. The long-term goal of the lab was to develop physically-based lighting models and perceptually based rendering procedures to produce images that were visually and measurably indistinguishable from real-world images. The work of the faculty and students has spawned much of the accurate lighting capabilities now present in commercial software. Roy Hall was instrumental in the development of the Abel Image Research raster system, and contributed to the Wavefront renderer (he also wrote the important book *Illumination and Color in Computer Generated Imagery*, published by Springer-Verlag in 1989.) The popular renderer Lightscape was also a result of Cornell research.



The Vermeer Studio

Since its founding the lab has researched and refined a framework for global illumination incorporating light reflection models, energy transport simulation, and visual display algorithms. The goal was to solve these computationally demanding simulations in real time using an experimental cluster of tightly coupled processors and specialized display hardware. They are achieving this goal by taking advantage of increased on-chip processing power, distributed processing using shared memory resources, and instructional-level parallelism of algorithms. The graphics research also involved three-dimensional modeling of very complex environments and new approaches for modeling architectural designs.

In 1991, the Program of Computer Graphics moved to the new Engineering and Theory Center Building across campus, now renamed Rhodes Hall as a tribute to Dr. Frank H.T. Rhodes, the former president of Cornell. Also in 1991, Cornell became one of five universities participating in the new National Science Foundation Science and Technology Center for Computer Graphics and Scientific Visualization (see Section 5 in this Chapter.) The *list of Cornell alumni* reads like a who's who in graphics, and the research publications coming from the lab are some of the most significant contributions of any lab in the world.

Greenberg received the ACM-SIGGRAPH Coons award in 1987 for his lifetime contribution to computer graphics and interactive effects.

**Movie 5.1** Cornell in Perspective

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/cip-2.m4v

*In 1971, Greenberg produced an early sophisticated computer graphics movie, Cornell in Perspective, using the General Electric Visual Simulation Laboratory.*

Some of this material was taken from an article in *Architecture Week* about the graphics program at Cornell, and from the history of the *Program of Computer Graphics* on Cornell's web site.

Cornell was one of 12 research labs showcased in an exhibition at SIGGRAPH 98 for the 25th anniversary of the conference. Their portion of the exhibition can be found at
*http://www.graphics.cornell.edu/siggraph/1998images.html*

Donald P. Greenberg, *An Interdisciplinary Laboratory for Graphics Research and Applications*, Proceedings of the Fourth Annual Conference on Computer Graphics, Interactive Techniques and Image Processing – SIGGRAPH, 1977

Cornell student Marc Levoy did his Bachelors and Masters work around 2D cartoon animation. His work led to a production system at Hanna Barbera Productions. As Levoy stated in an interview related to the Sands Award given for the best undergraduate research work in 1976:

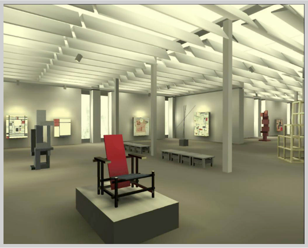
> "After the completion of my Master's thesis, Don Greenberg and I tried to convince the Walt Disney's feature animation group to incorporate computer graphics into their production process. Unfortunately, several of the "nine old men", who had worked for Disney since the 1930's, were still active, and they would have none if it. By the mid-1980's, these gentlemen had all retired, and Pixar was able to convince Disney to explore the new technology. The system they co-developed was called CAPS (Computer Animation Production System). It ultimately won them an academy award in 1992 for its use in Beauty and the Beast.
>
> Although we were unsuccessful at Disney, we managed to convince Hanna-Barbara[sic] Productions

> to employ our system in the television animation market. Hanna-Barbara was on the verge of closing down domestic production due to spiraling labor costs, and they saw our system as a way to forestall doing this. The animator's union didn't believe them, nor did they relish the prospect of computerization, leading to a bitter strike in 1982. In the end, the animators learned to use our system, which remained in production until 1996. At its peak in the late 80's, one third of Hanna-Barbera's yearly domestic production went through our system, including The Flintstones, Scooby Doo, and other shows. Ultimately, domestic labor costs become too high even for the computerized production line, and the the system was sold to James Wang Films of Taiwan. It has since been ported to PCs and is currently marketed under the name Animaster. The original technical team at Hanna-Barbera Productions consisted of myself, Bruce Wallace, Chris Odgers, Bennett Leeds, Jim Mahoney, Steve McDaniel, and Tim Victor. Our chief power user from the production side of the company was Ann Tucker. Interestingly, Ann subsequently went to work for Disney, becoming their chief power user as well."

Levoy worked as director of the Hanna-Barbera Animation Laboratory from 1980 to 1983.

**Gallery 5.1** Cornell PCG Images

Frank Lloyd Wright's Fallingwater by Matt Hyatt and Stephen Holley of the Cornell University Program of Computer Graphics. The building's first floor is the centerpiece of the model. Comprised of 150,000 triangles and numerous texture maps, it is used to test global illumination algorithms.



Rendered using radiosity techniques developed at Cornell University PCG. The image appeared on the proceedings cover of SIGGRAPH 1988.

Keith Howie of the Cornell PCG modeled this Hewlett-Packard 800 series workstation in 1989. This image appeared on the cover of IEEE Computer Graphics & Applications in January, 1991. A version of this image also appears in the back of Computer Graphics, Principles and Practice, by Foley, van Dam, Feiner and Hughes.

Dani Lischinski, Filippo Tampieri and Donald P. Greenberg created this image for the 1992 paper Discontinuity Meshing for Accurate Radiosity. It depicts a scene that represents a pathological case for traditional radiosity images, many small shadow casting details. Notice, in particular, the shadows cast by the windows, and the slats in the chair.

The Magritte Studio by Michael Cohen (1985) of the Cornell Program of Computer Graphics. This image was created using the hemi-cube algorithm developed at Cornell.

The Radiosity Factory from Cornell University. This image was rendered by Michael F. Cohen, Shenchang Eric Chen, John R. Wallace and Donald P. Greenberg for the 1988 paper A Progressive Refinement Approach to Fast Radiosity Image Generation. The factory model contains 30,000 patches, and was the most complex radiosity solution computed at that time. The radiosity solution took approximately 5 hours for 2,000 shots, and the image generation required 190 hours, each on a VAX8700.

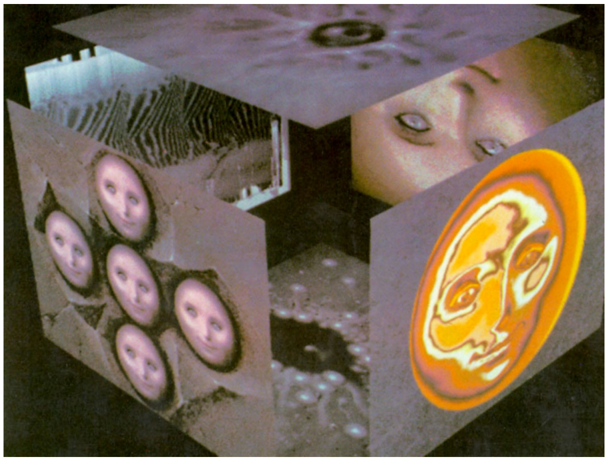
CG image of a samovar vase created at Cornell PCG.

## New York Institute of Technology (NYIT)

**Alexander Schure**, a wealthy entrepreneur from New York, was interested in making a feature length movie, and after attempting the process with traditional animation, became enamored with and wanted to use computers to do it.

In 1953 Schure got into the business of providing veterans with correspondence courses, and in 1960 his school was accredited as New York Institute of Technology, or NYIT. Expanding his campus from NewYork City, he bought an old industrialist estate in Westbury on Long Island in 1963. His first movie attempt was in the early 1970s, a traditional animation project called *Tubby the Tuba*, which ultimately failed miserably.

Schure's board of directors included members of the wealthy Rockefeller family, who also served on the board of the computer graphics company Evans and Sutherland in Utah. In 1974, Dr. Schure made a commitment to the computer film project by establishing the *Computer Graphics Laboratory* (CGL) at NYIT. The Rockefellers suggested that he visit E&S in Utah to get a sense of the kinds of technology that was available. He put together one of the most sophisticated studios of the time on the NYIT campus on Long Island, employing CGI equipment and state of the art computers that he obtained from E&S, but also top end analogue devices for doing special effects. He also was interested in top talent, and looked to the University of Utah to find this talent after having been exposed to the animated face and hand produced by Ed Catmull and Fred Parke. He hired Catmull (who had left Utah for the CAD company Applicon) and fellow Utah grad Malcolm Blanchard to run his facility, and they were soon joined by Alvy Ray Smith and David DiFrancesco, and later Lance Williams, Fred Parke, Garland Stern, and others, including many from Utah. He also attracted other technology experts and artists, including Jim Clark, Ralph Guggenheim, Ned Greene, Rebecca Allen and Ed Emshwiller, who was a Hugo award winning artist who had recently won a Guggenheim grant to make a film. Emshwiller worked with Stern, Williams and Smith and other NYIT staff to make the now famous film *Sunstone* in 1979.

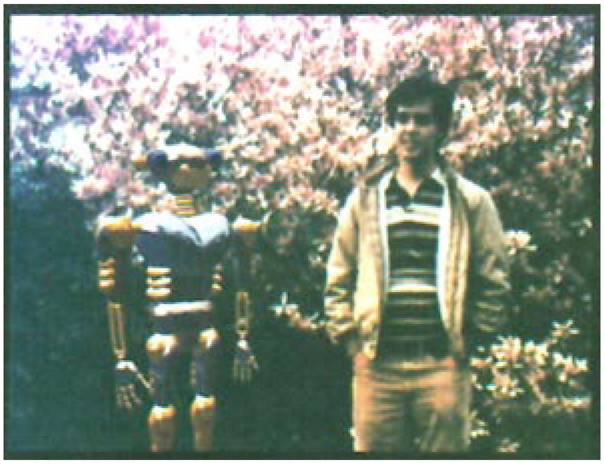


*Frame from Sunstone*

The personnel at NYIT CGL were very prolific in the design of influential software during the period from 1975 to 1979, including the animation program *Tween*, the paint program *Paint*, the animation program *SoftCel*, and others. They also contributed to image techniques involving *animation*, fractals, morphing, *image compositing*, texture mapping (the famous *Mip-Map* approach), digital conversion of video signals, scanning of animated frames, and many other innovations.

The NYIT staff, most notably Gene Miller, Lance Williams and Michael Chou, were responsible for an innovative rendering technique called "**reflection mapping**", which was later used to provide realism to shiny objects in television and the movies (eg, *Flight of the Navigator, Terminator,* and *The Abyss*).

One of the first such images (shown here) was done by Chou, showing him standing next to a shiny synthetic robot. NYIT published the technique at SIGGRAPH in 1982 and 1984, and in 1985 used the technique in a short video titled *Interface*.



*Michael Chou and his robot*

Another innovation out of NYIT, arguably one of the most influential, was the **alpha channel**. This contribution made it possible to combine two images or parts of images, and to recognize the impact of transparency in the combination. As Alvy Ray Smith said in his 1995 technical memo, *Alpha and the History of Digital Compositing*

"Ed Catmull and I invented the notion of the integral alpha in the 1970s at New York Tech. This is the notion that opacity (or, equivalently, transparency) of an image is as fundamental as its color and should therefore be included as part of the image, not as a secondary accompaniment. To be very clear, we did not invent digital mattes or digital compositing. These were obvious digital adaptations of known analog techniques. We invented the notion of the alpha channel as a fundamental component of an image. We coined the term 'alpha' for the new channel. We called the resulting full-color pixel an 'RGBA' pixel."

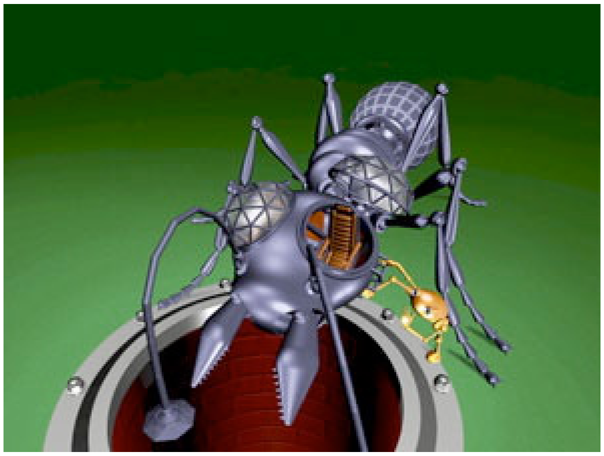
Alpha compositing was further developed in a *1984 paper* by Tom Porter and Tom Duff at Lucasfilms.

Smith developed the 8-bit program *Paint*, which was sold to Ampex and became the main components of the Ampex AVA system. This system was used by artist LeRoy Niemann to do interactive painting during Superbowl XII in 1978. *Paint* and Smith's later 24-bit *Paint3* had a great deal of influence on subsequent systems, including the paint system at Lucasfilm and the CAPS system developed for Disney by Lucasfilm.

After *Tubby the Tuba* failed in the way that it did, many of the traditional animation staff left NYIT, and the emphasis on 3D moved forward. CGL worked on highly visible ads and television promotions for clients such as NOVA and ABC Sports.

Several videos from NYIT have become quite famous: *Sunstone*, *Inside a Quark*, by Ned Greene, and *The Works*, as well as some documentary work by Rebecca Allen. A great deal of effort at NYIT went into the development of the film "*The Works*", which was written by Lance Williams[1]. For many reasons, including a lack of film-making expertise, it was never completed. Sequences from the work in progress still stand as some of the most astounding animated imagery of the time.

Many of the researchers at CGL were becoming disillusioned with Schure and the way he ran the facility, so they quietly looked for different opportunities elsewhere. The quality of the imagery, along with the other research and technology work at NYIT attracted the attention of George Lucas, who was interested in developing a CGI special effects facility at his company Lucasfilm. He sent one of his top people, Richard Edlund, to scope out what was going on at the Long Island lab. He soon after recruited much of the top talent from NYIT, including Catmull, and Smith and Guggenheim (who both took on a short stint at JPL) to start his division, which eventually was spun off as Pixar.



*An article on The Works was featured in the trade magazine Computer Pictures in 1983*

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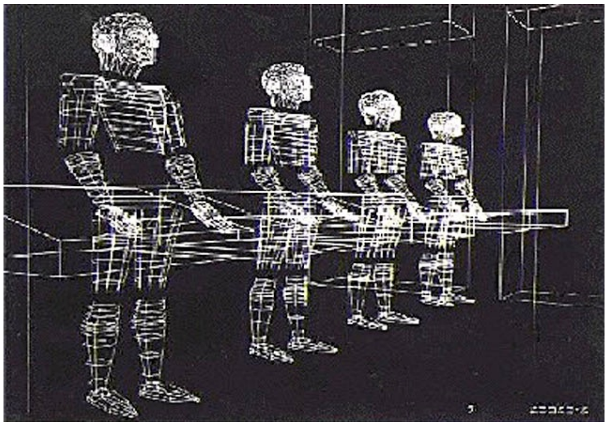
[1] Lance Williams passed away on August, 20, 2017. Hank Grebe, who worked with Williams at NYIT, eloquently paid tribute to him with a quote of the last paragraph of "The Works" script: *"Beeper and Ipso gazed at the ship landing on the screen , and the boy and the robot and the vastness of the Works itself dwindled to tiny points on the earth, and the earth, to a tiny point among the stars, and the stars lost their identity in clouds of galaxies, and when the inconceivably vast clusters of the galaxies are indistinguishable in the milky swirl of the infinity of space, some people will still be wondering if the Universe is large enough to include a story as unlikely as this one."*



Scene from Kraftwerk music video – Rebecca Allen

Work continued after the departure of some of the originators of the CGL facility. Rebecca Allen, who came to NYIT from MIT, won an Emmy for work done for *Walter Cronkite's Universe*, and she later did several music videos, including work for Kraftwerk and Peter Gabriel. The French company Thompson Digital Image, or TDI, bought the rights to use Garland Stern's system BBOP, as did Omnibus in Canada.

Schure never got over the move of his top talent from NYIT, and he attempted to obtain patents on many of the innovative algorithms that were developed there by them. He was unsuccessful, in large part because he was so late in filing, because many had been published at SIGGRAPH and elsewhere, and because Microsoft and Pixar fought those attempts. Schure eventually succumbed to Altzheimer's disease in 2009.

Ed Catmull and Lance Williams received the ACM-SIGGRAPH Coons award in 1993 and 2001 respectively, for lifetime contribution to computer graphics and interactive effects. Williams also received an Academy Award for Technical Achievement in 2002 for his influence in the field of computer generated animation and effects for motion pictures. Garland Stern received an Academy Award for Technical Achievement in 2001 for the Cel Paint Software System. Alvy Ray Smith received the ACM-SIGGRAPH Computer Graphics Achievement award in 1990 for an outstanding contribution to computer graphics and interactive effects. He also received an Academy Award for Technical Achievement in 1997 for his paint system.

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(027)

A New York City office of NYIT's CGL was established to market and sell the technology developed in Westbury. Also called CGL, it focused on the emerging television advertising and promotions industry. CGL sold hardware and licenses to the *Images* and *Images II* production systems to many other companies, including Omnibus in Toronto and JCGL in Japan.

**Movie 5.2** Sunstone

Sunstone (1979) Ed Emshwiller (with Alvy Ray Smith, *Lance Williams, Garland Stern)* *http://www.youtube.com/watch?v=tMW15OajuKc*

**Movie 5.3** Excerpt from *The Works*

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/works.m4v

**Movie 5.4** The Works (1984)
*http://www.youtube.com/watch?v=18OSLeWJVJQ*

**Movie 5.5** Kraftwerk *Musique Non Stop* music video graphics by Rebecca Allen
*http://www.dailymotion.com/video/x175jh_kraftwerk-music-non-stop_music*

**Movie 5.6** JCGL Demo Reel 1983
*https://www.youtube.com/watch?v=_WlAnrdtGmg*

Porter, Thomas, and Duff, Tom, *Compositing Digital Images*, Computer Graphics, Vol 18, No 3, Jul 1984, 253-259. SIGGRAPH'84 Conference Proceedings.

Smith, Alvy Ray, Image Compositing Fundamentals, Tech Memo 4, Microsoft, Jun 1995.

Smith, Alvy Ray, *Alpha and the History of Digital Compositing*, Tech Memo 7, Microsoft, Aug 1995.

An article on The Works was featured in the trade magazine *Computer Pictures* in 1983.

A great compilation of NYIT information can be found at Paul Heckbert's site at *http://www.cs.cmu.edu/~ph/nyit/*.

Alvy Ray Smith wrote an article describing the Paint program as part of a survey of activities related to digital ink and paint called *Digital Paint Systems*, a Microsoft Technical Memo.

Alvy Ray Smith wrote an interesting account of he and Ed Emshwiller and the creation of Sunstone, now at the computer history site, and can be read at http://www.computerhistory.org/atchm/alvy-ed/

Heckbert wrote a personal account of the participation of the NYIT staff in the making of the IMAX movie "*The Magic Egg*" for the 1984 SIGGRAPH conference in Minneapolis.

A 2007 NYIT Alumni article titled "Out of this World: Meet the NYIT scientists and alumni who amazed Silicon Valley, astonished Hollywood and engineered the 3-D computer animation universe" can be accessed here.

In 1989, Quantel, Ltd. filed suit in British courts accusing Spaceward, Ltd. of violating their claim to have invented digital "airbrushing" and digital compositing. Alvy Ray Smith testified as to his development of the concepts earlier than the claim of Quantel, but to no avail. Spaceward lost the case, and their product. Smith commented, in his paper *Digital Paint Systems: An Anecdotal and Historical Overview*, in 2001, that he had done this work while at NYIT in 1977: "To my mind, airbrushing and digital compositing are the same thing: One combines one image with another, using a third for transparency control."

In 1996 a patent infringement case was again filed by Quantel Ltd. against Adobe Systems, Inc., accusing Adobe Photoshop's "paint" feature of infringement. A jury ultimately found Quantel's patents invalid because they covered basic software techniques developed in 1977 by Alvy Ray Smith, a computer graphics pioneer and co-founder of Pixar Animation Studios. Smith had sold his paint system to Ampex in the mid 1970s and briefly described his digital paint systems in "tutorial notes" distributed at conferences in 1978. The source code that implemented Smith's paint systems was not itself readily accessible, yet it is fair to say modern computer graphics evolved, in large part, from Smith's groundbreaking work.
From T*aking Care of Business – Patent reform should promote innovation, not imitation*, by Kelly C. Hunsaker. San Francisco Chronicle, August 30, 2005

This case was documented in an article in Computer Graphics in August, 1998, *Computer graphics in court: the Adobe/Quantel case*, by Dick Phillips.

The results of the case were outlined in a 1997 article, Adobe Defeats Infringement Claim, found at *http://www.litstrat.com/Cases/ADOBEtest.pdf*

**Gallery 5.2** NYIT Image Collection

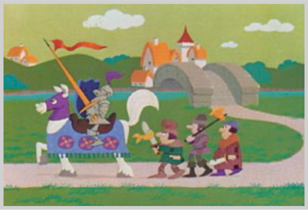
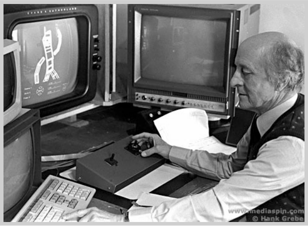


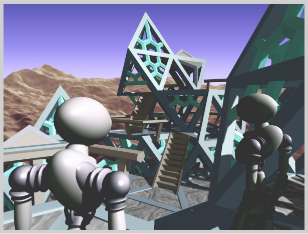
Image created with Paint

Image transformation

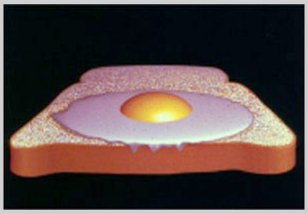


Arthur Clokey, the creator of Gumby, works on the E&S graphics display, which was the heart of the NYIT CGL system. to create a digital version of the popular character (Hank Grebe and Dick Lundin, 1984)?For more information from http://www.mediaspin.com/gumby.html

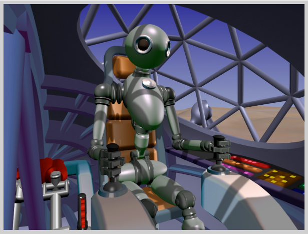
Raspberries of Kyoto – Peter Oppenheimer



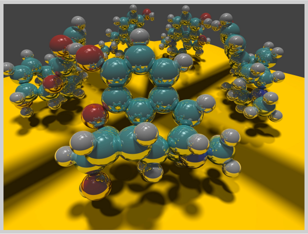
Mondo Condo – Ned Greene



Paint image – Alvy Ray Smith



Driver (Ant Jockey) from the Works – Dick Lundin and Ned Greene (1983)



Ray tracing with soft shadows – Paul Heckbert

Scene from Kraftwerk music video – Rebecca Allen

Saxobone (1982) – Dick Lundin

Synthesized maple tree – Jules Bloomenthal

Dimetrodon – Dick Lundin

# 5.2 UNC and Toronto

## UNC

**Henry Fuchs** arrived at the University of North Carolina at Chapel Hill in 1978, after completing his PhD at the University of Utah.[1] His early work was in the area of binary space partitioning (BSP) trees for optimal determination of visibility in computer generated scenes, 3D data acquisition and construction, and moved to high performance architectures for graphics and hardware visualization techniques. He was appointed the Federico Gil Professor of Computer Science and adjunct professor of radiation oncology, after starting in computer graphics and image processing in 1969. Prof. Fuchs served on the editorial board of ACM Transactions on Graphics from 1983 to 1988, and was the guest editor of its first issue (January 1982). Fuchs received the 1992 Computer Graphics Achievement Award from ACM-SIGGRAPH and the 1992 National Computer Graphics Association Academic Award. He was also selected as an ACM Fellow.

In 1980, the faculty and students at the Graphics and Image Analysis Research center at UNC began exploring computer architectures for 3D graphics that were significantly faster than traditional architectures for applications that required high performance, such as medical visualization. The project that Fuchs started was called Pixel-Planes, and had an emphasis on scalability and real-time rendering.

The principle techniques used revolved around a plane of processors, each with a few bytes of its own memory, operating in unison. Each pixel (picture element) on the screen was associated with a unique processor. Since each processor knew its x and y screen coordinates, the system sent out the equation for a line and each processor computed which side of the line it was on. Sending the equations for three lines allowed for the computing of which processors were inside the lines and how far away from the viewer's perspective each pixel was. The shading and texturing each of the pixels was done in a similar rapid manner.

The first machine built at UNC under the project was Pixel-Planes 2. Its screen resolution was 4×64 pixels, and only 16 bits of memory per pixel, and was only able to display a few polygons per second. Yet, even with those

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[1] Much of this account is taken from the lab description at the UNC website.

statistics, this early prototype showed the power of the concepts. Pixel-Planes 4 was a machine that had an array of 512×512 processors operating in synchrony. Each pixel processor had 72 bits of memory at its disposal. The video image was produced directly from what is stored in the memory, and a front-end processor based upon a Weitek chip set performed the initial geometry computations, the results of which were fed to the processor array. This machine could draw at the rate of about 40,000 triangles per second. Pixel-Planes 5 solved some of the problems of Pixel-Planes 4, such as the idleness of the processors when computing images comprised of small polygons.

Instead of a single 512×512 array, it had multiple 128×128 arrays (up to about 20 of them). Each of the processors had 208 bits of primary memory available, plus 4096 bits of secondary memory. In addition, instead of a single geometry processor, there were many (up to about 50) Intel i860 processors. Rather than generate the video image from the memory of the processor arrays, the data was sent to a separate frame buffer. This also allowed the use of multiple frame buffers of various types, including a high resolution (1280×1024) model. The net result of the system was a rendering rate of over 2 million triangles per second.

The next generation machine, PixelFlow (PxFl) used pairs of geometry processors and array processors working independently to create screen-sized images based on the subset of the triangles that they have. The partial images were then combined into one by performing a depth-wise sort using a special high-speed image composition network.

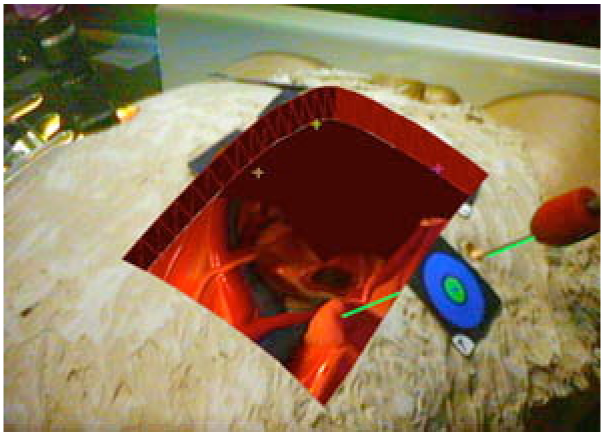
*The nanoManipulator*

Besides Pixel-Planes, the UNC group worked on virtual environments and other related projects. Fred Brooks, who started the Computer Science Department at UNC in 1964 oversaw that work. Brooks' contributions were broad, from computer architecture, to human computer interaction, to virtual environments. He was widely published (he was the author of the excellent book, *The Mythical Man Month* (1975)). He received many awards for his activities, including the National Medal of Technology, the A.M. Turing Award from ACM, John Von Neumann Medal from IEEE, and was both an ACM Fellow and an IEEE Fellow. Brooks' research on real-time, three-dimensional computer graphics propelled that field forward, driven by the goal of creating tools that enabled scientists and engineers to tackle problems formerly beyond their reach.

The UNC team built the first molecular graphics system on which a new protein structure was solved. They also first proved that **haptic** displays augmenting visual displays could significantly improve a scientist's understanding of data.

Brooks was assisted on the research for VR and haptics by Mary Whitton and others. They developed several systems, including Grip, Grope and Docker. They connected haptic feedback to the microscope, and extended it to passive haptics for determining feel such as standing on a ledge.

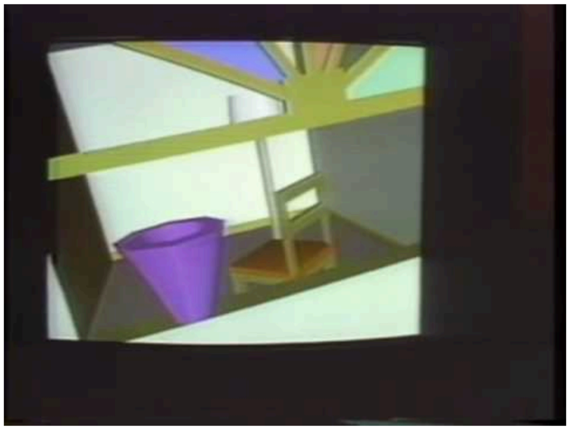
*The Docker haptic feedback system*



*Augmented Reality ultrasound visualization*

The ultrasound research group at UNC developed a *prototype real-time augmented reality system* based on an SGI Onyx workstation equipped with a real-time video capture unit. The camera captured both HMD camera video and ultrasound video. The camera video was displayed in the background; the ultrasound video images were transferred into texture memory and displayed on polygons emitted by the ultrasound probe inside a virtual opening within the scanned patient. This system was used to demonstrate the possibility of using augmented reality to enhance visualization for laparoscopic surgery.? (Portions of the above text were taken from the UNC Computer Science research webpages.)

**Movie 5.7** Pixel Planes



*Pixel Planes 4 was one in a series of graphics systems developed at the University of North Carolina in the 1980s. https://www.youtube.com/watch?v=7mzpZ861wEw*

Henry Fuchs list of graphics publications can be viewed online at *http://www.cs.unc.edu/~fuchs/publications2011.html*

A summary of publications from the UNC research projects can be viewed online at *http://telepresence.web.unc.edu*

## University of Toronto

The University of Toronto Dynamics Graphics Project (*dgp*) was founded in 1967 by Professor Leslie Mezei. He was joined by Professor **Ron Baecker** in 1972, who coined the name Dynamic Graphics Project in 1974, when they got their first stand-alone machine, a PDP11/45 with a highly-interactive display informally called the Graphic Wonder. Baecker had completed his PhD in 1969 at MIT, working on the *GENESYS animation system*.

The *dgp* lab's name was intended to imply the spirit of the place, and to encompass both Computer Graphics and Dynamic Interaction Techniques, which was subsumed by the new field of Human Computer Interaction in the early 1980's. Under the leadership of Baecker, Alain Fournier, Bill Buxton, and Eugene Fiume, *dgp* became a world academic leader in both computer graphics and human-computer interaction. The lab's alumni are now on faculty at top universities throughout the world and at major industrial research labs, and have also won academy awards for their groundbreaking work.

Other early work included the Smalltalk animation system SHAZAM. An early animated film done by Baecker called *Sorting Out Sorting* showed the value of animation in teaching complex concepts.

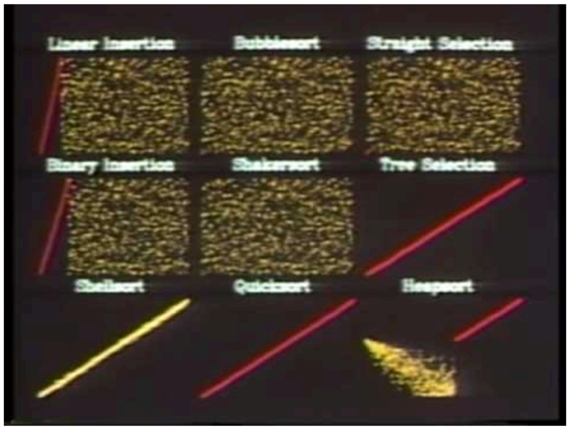
The *dgp* at Toronto was very closely tied to the development efforts at Alias, headquartered in Toronto (see more about Alias in Chapter 8.) As was stated in the document referenced at the beginning of this section:

"The *dgp*-Alias partnership began in 1992. Alias was recovering from a financial downturn with renewed investments in R&D for computational tools for design and entertainment. Computational power had by then reached the stage where high-quality interactive graphics was within reach, but a great deal of basic research was still needed. Alias collaborated with various universities on mathematical techniques for modeling surfaces, and on animating and rendering geometric models. However, the modeling of natural phenomena such as smoke, fire, clouds and water was embryonic research. By 1994, Eugene Fiume and his then student Jos Stam demonstrated a new way to model "gaseous and fluid phenomena" that was then licensed by Alias. Stam and Fiume worked with engineers from Alias to integrate these techniques into the Alias design product with astonishing success: the enhanced product drew considerable attention from film animators, and the (now) world- renowned animator, Chris Landreth, while working at Alias, used this technology often in completely unexpected ways to create an Academy Award nominated film called "the end". Dozens of film productions used this work in short order, routinely including Landreth himself, who ten years later won an Academy Award in 2005 for his beautiful film “Ryan”. This film incidentally also involved members of *dgp*. Jos Stam joined Alias and continued a string of innovations that make him among the most highly cited researchers in computer graphics. His efforts were recognized in a “Computer Graphics Achievement Award” presented by the premier organization in the field, ACM SIGGRAPH. After more years of enhancement, Stam and his colleagues at Alias won a Technical Academy Award for their fluid simulation software. The story has come around full circle, as Stam is now an Adjunct Professor in the Department of Computer Science at the University of Toronto, working with several students in *dgp*.

Likewise, in the early 1990s, Gord Kurtenbach developed an innovative user interface dialogue technique called “Marking Menus” as part of his Ph.D. work in *dgp* under the supervision of **Bill Buxton**. This technology was also transferred to Alias and became central to distinguishing the workflow and user interface of Alias from its competitors. Both Buxton and Kurtenbach then joined Alias, forming the core of a new research group at Alias. This was among the first groups in industry to focus on fundamental research on human-computer interfaces and on usability engineering. The group, strengthened by more *dgp* graduates such as George Fitzmaurice and Russell Owen, quickly established an international reputation in HCI, publishing a series of highly cited papers. Bill Buxton went on to become a Chief Scientist of the company.

Fiume joined Alias for several years starting in 1995, going on to establish broadly based Research and Usability Engineering department. This set the stage for a similar growth in computer graphics research as Buxton spearheaded in HCI: Karan Singh and Jos Stam joined the research group, developing new techniques in geometric modeling, deformations, and the modeling of natural phenomena. When Fiume returned to the University of Toronto to chair the Department of Computer Science in 1998, Kurtenbach took over as Director of Research, and both Kurtenbach and Fitzmaurice became Adjunct Professors in the department. By then the Alias Research group was a world leader in both HCI and computer graphics.”

**Movie 5.8** Sorting Out Sorting (Excerpt)



*“Sorting Out Sorting” was developed to visualize the processes used in different data sorting algorithms.*
*https://www.youtube.com/watch?v=gv0JUEqaAXo*

Baecker, R.M. (1969). Picture-Driven Animation. Proceedings of the AFIPS Spring Joint Computer Conference, 273-288.

Baecker, Ronald M. (1969). Interactive Computer-Mediated Animation. PhD Thesis, MIT.
*http://www.lcs.mit.edu/publications/pubs/pdf/MIT-LCS-TR-061.pdf*

Baecker, R.M., Smith, L., and Martin, E., *GENESYS – An Interactive Computer-Mediated Animation System*, system demonstration film, MIT Lincoln Laboratory, 1970.

Buxton, William (2005). Interaction at Lincoln Laboratory in the 1960's: Looking Forward — Looking Back. Panel Introduction. Proceedings of the 2005 ACM Conference on Human Factors in Computing Systems, CHI'05, April 3-7, 2005, 1163-1167.
*http://billbuxton.com/LincolnLab.pdf*

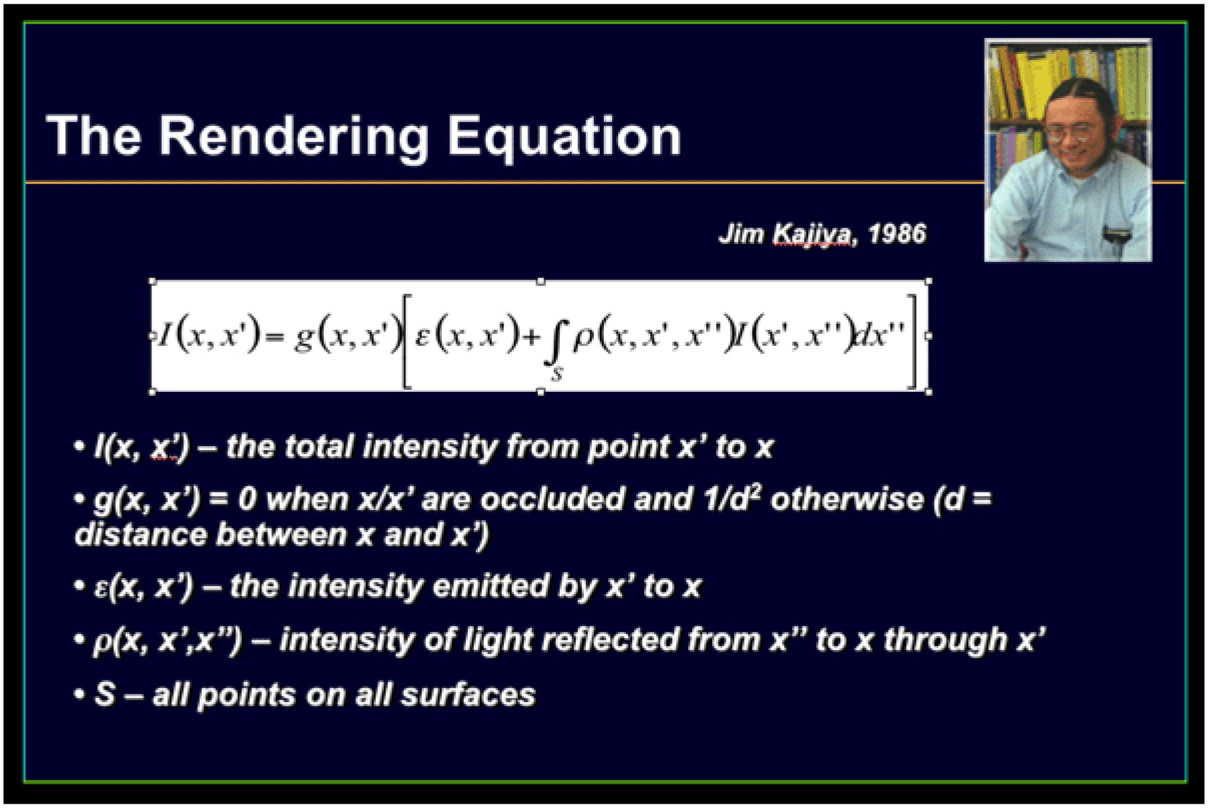
# 5.3 Cal Tech and North Carolina State

## Cal Tech

The Computer Science Department at Cal Tech was started in 1976 by Robert Cannon, then U.S. Assistant Secretary of Transportation for Systems Development and Technology. He organized a search committee to recruit top faculty to the new department, and one of his first recruits was Ivan Sutherland (who was appointed as the Fletcher Jones Professor of Computer Science). **Jim Kajiya** was recruited by Sutherland in 1979, and they were later joined by **Al Barr** and Jim Blinn, who with Kajiya formed the core of the Cal Tech research group in computer graphics, which was probably the most mathematically sophisticated computer graphics group in the country. The group developed fundamental mathematical approaches for computationally simulated physical objects.?? Barr's work in graphics was dedicated to creating a unified mathematical formalism for representing the shape and the behavior of objects. Kajiya was working toward connecting computer graphics principles to the basic equations of electromagnetism that govern the behavior of light. Blinn was recruited to Cal Tech as a half-time research fellow (later lecturer) by Sutherland. His primary interest was in the space program, and Blinn spent the other half of his time at the Jet Propulsion Laboratory producing animated simulations of the Voyager missions to Jupiter and Saturn.

Kajiya had a Utah PhD, but his fields of interest were very high-level programming languages, theoretical computer science, and signal processing. His interest in computer graphics began in 1981, after he presented a paper at the national SIGGRAPH conference on different ways of manipulating pixels (individual picture elements) to get a sharper image in the display of characters on CRT screens. Kajiya met Al Barr in the summer of 1983, when they were both speakers at the SIGGRAPH seminar on the state of the art in computer graphics. At that time Barr was senior research scientist at Raster Technologies, Inc. and was finishing his thesis at Rensselaer Polytechnic Institute. He was about to accept a faculty position at MIT, but Kajiya convinced him to come to Cal Tech instead.

Kajiya was also interested in **anisotropic reflection**, that is, reflection from surfaces such as cloth, hair, or fur. They worked on the mathematical methods used for the what Kajiya called the "fuzzy object problem", the simulation of hair, fire, fabric, and splashing water, as well as simulating the shapes and appearance of plants and animals. The group also produced 4 out of the 19 contributions to the 1985 **Omnimax** film shown at SIGGRAPH 95. Barr animated a giant school of graceful sperm cells swimming toward a looming, "undulating egg cell", and JPL's Jeff Goldsmith, with software by Kajiya and Blinn, contributed a fly-by of Saturn. The third film was a sequence based on the constellations, with software written by Blinn. Kajiya, with computer science grad students Tim Kay and Brian Von Herzen, together with help from Art Center students, contributed a 30 second animation of a flight into a space colony (which just happened to house the Cal Tech campus).



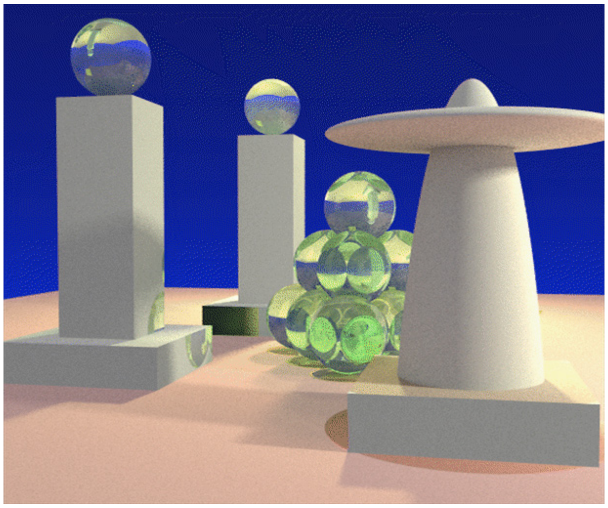
## The Rendering Equation

*Jim Kajiya, 1986*

$$I(x,x') = g(x,x')\left[\varepsilon(x,x') + \int_S \rho(x,x',x'')I(x',x'')dx''\right]$$

- *$I(x, x')$ – the total intensity from point x' to x*
- *$g(x, x') = 0$ when x/x' are occluded and $1/d^2$ otherwise ($d$ = distance between x and x')*
- *$\varepsilon(x, x')$ – the intensity emitted by x' to x*
- *$\rho(x, x',x'')$ – intensity of light reflected from x'' to x through x'*
- *S – all points on all surfaces*

1986, Kajiya introduced *the rendering equation* as a way of modeling global illumination in an environment arising from the interplay of lights and surfaces. The rendering equation and its various forms have since formed the basis for physically-based rendering, enabling a new level of realism.



*Caustics and color bleeding*

Other Cal Tech researchers besides Kay and Von Herzen included Andrew Witkin, David Kirk, Kurt Fleischer, Ronen Barzel, David Laidlaw, John Platt and others. Jim Kajiya received the ACM-SIGGRAPH Graphics Achievement Award in 1991 for an outstanding contribution to computer graphics and interactive effects. He and Tim Kay also received an Academy Award for Technical Achievement in 1996 for their work in generating fur and hair for motion pictures. A list of publications out of the Cal Tech Graphics group can be found at *http://www.gg.caltech.edu/publications.html*

Cal Tech was one of five universities (Brown, UNC, Utah, Cornell, and Cal Tech) across the country that were part of the NSF funded Graphics and Visualization Center, founded in 1991. It was one of 24 National Science Foundation Science and Technology Centers created to pursue foundational interdisciplinary research. The primary goals of the Center were to build a stronger scientific foundation for computer graphics and scientific visualization and to help create the basic framework for future interactive graphical environments (see section 5 in this chapter.)

## Research Areas

The Cal Tech Computer Graphics Group pursued research in four main areas of computer graphics, with a focus on the mathematical foundations of CG: modeling, rendering, user interfaces and high-performance architectures. Two driving application areas helped direct this research: scientific visualization and telecollaboration in virtual environments. Center researchers developed new rendering algorithms based on the physics of light, new physically-based models, sophisticated mathematics for 3D surface definition, new parallel display architectures, easier-to-use 3D user interfaces for individual and collaborative work on the desktop and in virtual environments, and new techniques for scientific visualization.

Books (*) and selected publications

*Barzel, Ronen. *Physically-Based Modeling for Computer Graphics: A Structured Approach*. San Diego: Academic Press, 1992. Abstract is available

*House, Donald and David Breen, eds. *Cloth Modeling and Animation*. Natick, MA: AK Peters, 2000.

*Kirk, David, ed. *Graphics Gems III*. San Diego: Academic Press, 1992.

*Snyder, John M. *Generative Modeling for Computer Graphics and CAD: Symbolic Shape Design Using Interval Analysis*. San Diego: Academic Press, 1992. Abstract is available.

Kajiya, James T., “The rendering equation,” in *Proceedings of SIGGRAPH 1986,* ACM SIGGRAPH, 1986, pp. 143-150.

Witkin, Andrew, Kurt Fleischer and Alan H. Barr, "Energy constraints on parameterized models," in *Proceedings of SIGGRAPH 1987*, ACM SIGGRAPH, 1987, pp. 225-232.

Terzopoulos, Demetri, John Platt, Alan H. Barr and Kurt Fleischer, "Elastically deformable models," in *Proceedings of SIGGRAPH 1987*, ACM SIGGRAPH, 1987, pp. 205-214.

Barzel, Ronen and Alan H. Barr, "A modeling system based on dynamic constraints," in *Proceedings of SIGGRAPH 1988*, ACM SIGGRAPH, 1988, pp. 179-188.

Snyder, John M., "Interval analysis for computer graphics," in *Proceedings of SIGGRAPH 1992*, ACM SIGGRAPH, 1992, pp. 121-130. Abstract is available.

Snyder, John M. and James T. Kajiya, "Generative modeling: a symbolic system for geometric modeling," [Figures], in *Proceedings of SIGGRAPH 1992*, ACM SIGGRAPH, 1992, pp. 369-378. Abstract is available.

Fleischer, Kurt W., Bena Currin, David H. Laidlaw and Alan H. Barr, "Cellular texture generation," in *Proceedings of SIGGRAPH 1995*, ACM SIGGRAPH, 1995, pp. 239-248.

Greenberg, Donald, Kenneth Torrance, Peter Shirley, James Arvo, et al., "A framework for realistic image synthesis," in *Proceedings of SIGGRAPH 1997*, ACM SIGGRAPH, 1997, pp. 477-494.

## North Carolina State University

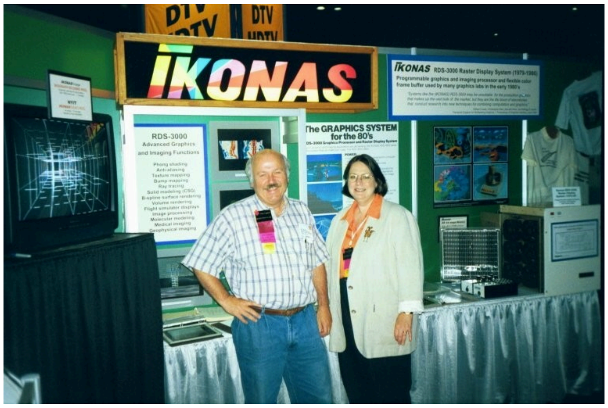
The graphics program at North Carolina State University was relatively short-lived, but the investigations that were conducted there had long term impact on the discipline. Prof. John Staudhammer (later with the Graphics Symbolic and Geometric Computation Program at NSF) created the research group in the Electrical Engineering Department around 1970. Students included Turner Whitted, Nick England, Mary Whitton, Jeff Eastman, Marc Howard, Ed Tripp and others. They had some success with research publications, and developed some lasting hardware configurations.

Nick England uses a RAND tablet with one of the NCSU raster displays

Eastman, Dave Wooten, and Tripp designed a very fast asynchronous parallel processor for graphics operations, and England designed and built the fore-runner to the Ikonas system, a programmable 32-bit graphics processor (based on AMD 2901) and a frame buffer (512x512x2 or 256x256x8), which was published in a paper at SIGGRAPH 78.

Staudhammer formed a company called Digitec and built the real-time playback run-length encoded frame buffer for the CGRG at Ohio State, and Whitton and England started Ikonas Graphics Systems based on the England's programmable raster display processor.

After receiving his PhD from NCSU in 1978, **Turner Whitted** left for Bell Labs and proceeded to impact the CGI world with an algorithm that could **ray-trace** a scene in a reasonable amount of time. His film, *The Compleat Angler* is one of the most mimicked pieces of CGI work ever, as nearly every student that enters the discipline tries to generate a bouncing ray-traced ball sequence. Whitted was also very instrumental in the development of various scan line algorithms, as well as approaches to organizing geometric data for fast rendering.



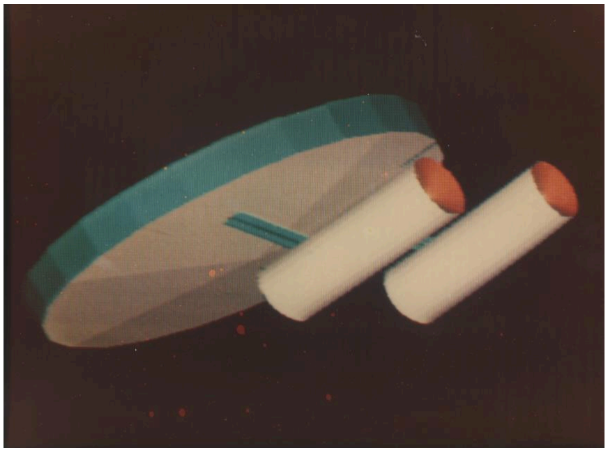
Nick England and Mary Whitton at the Ikonas booth at SIGGRAPH 98

In 1983, Whitted left Bell Labs to return to North Carolina to establish Numerical Designs, Ltd. (later part of Emergent Game Technologies) in Chapel Hill. NDL was founded with Robert Whitton of Ikonas to develop graphics toolkits for 3D CGI. Key developments of NDL included

- NetImmerse 3D Game Engine
- MAXImmerse 3D Studio MAX Plug-in
- PLUS Photorealistic Rendering Software

Whitted also had a faculty appointment at UNC, and in 1997 joined the graphics division at Microsoft. He was appointed an ACM Fellow, and received the 1986 SIGGRAPH Graphics Achievement award for his simple and elegant algorithm for ray-tracing. He became the lead contact for the Graphics group and the Hardware Devices group at Microsoft, where he investigated alternative user interface devices, such as wearable interfaces.

**Movie 5.9** NC State graphics



*Early computer graphics at NC State University Signal Processing Lab – circa 1973*
https://www.youtube.com/watch?v=4MHzU4xJ4pk

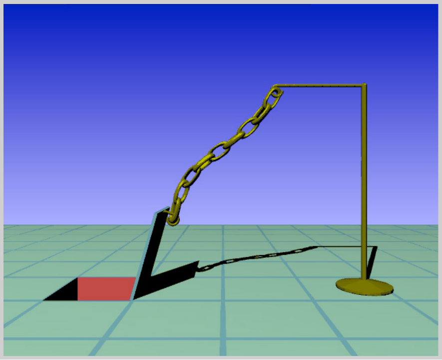
1984 article about Computer Graphics at Cal Tech
https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/caltech-graphics1984.pdf

An extensive list of Cal Tech books and publications can be found online at *http://www.gg.caltech.edu/publications.html*

For more information about the early work at NCSU, see *Nick England's NCSU page*.

**Gallery 5.3** Images from Cal Tech

Herbert the Bear with 3D textures



Pandora's Chain – Al Barr – CalTech

Living room – lighting and shadows

Generative modeling (Image appears on the cover of John Snyder's book)

Fleischer – Developmental modeling

# 5.4 Illinois-Chicago and University of Pennsylvania

## University of Illinois – Chicago Circle

Dan Sandin

**Dan Sandin** came to the University of Illinois at Chicago Circle from the University of Wisconsin in 1971 and developed the Sandin Image Processor, which could be thought of as the visual counterpart to the **MOOG synthesizer**. He was joined the next year by **Tom DeFanti**, who had developed the Graphics Symbiosis System (GRASS) as part of his PhD work with Chuck Csuri at the CGRG at Ohio State. Together, they organized the Circle Graphics Habitat, which became an environment for experimental computer graphics, video production, and educational materials development. Later in 1987, they were joined by Maxine D. Brown as Associate Director.

Some of the most important early work at the Habitat revolved around the Z Box (Z-50 processor) project, which resulted in the development of ZGRASS, which was an early PC-based graphics system for the Bally computer (1981). In the words of Jane Veeder, it provided

“…real time animation and real time sound synthesis accessed by a custom language optimized for interactive artmaking, all wrapped up together like a hot little sports car.”

The box had an NTSC video output port, which provided video recording and display capabilities for artists. DeFanti et al attempted to commercialize the product through their company, Real Time Design, Inc. Artist Larry Cuba produced an animated sequence for the movie *Star Wars* on the system at Chicago in 1977.

Tom DeFanti

Later contributions were in mathematics visualization and virtual reality, including the *CAVE environment* and the Immersadesk. DeFanti also contributed immensely to the SIGGRAPH organization, as its President and with contributions to their annual conference. DeFanti and the group at Chicago began a project to archive all of the films and videos shown at the SIGGRAPH conference, resulting in the SIGGRAPH Video Review (SVR). The Circle Graphics Habitat later became the Electronic Visualization Lab (EVL).

Research work at EVL over the years has included[1]:

- 1977: The Sayre Glove, the first dataglove.
- 1981: The Z Box hardware and ZGRASS software (based on DeFanti's prior GRASS programming language), an early graphics system for the Bally home computer. This system featured NTSC video output and was used by a number of computer graphics artists of the time.
- 1988: Computer generated PHSColograms, an autostereoscopic 3D technique, with (art)$^n$.
- 1992: The CAVE Automatic Virtual Environment, a projection-based virtual reality system.
- 1995: The I-WAY event at Supercomputing '95, a prototype of grid computing.
- 1997: The STAR TAP project, a linking up of several international high-performance networks. Followed by the StarLight optical networking facility.

Highlights of the electronic art work done at EVL include:

- Electronic Visualization Events (EVE) in the mid 1970s – live, real-time performances featuring computer graphics, video processing, and music.
- Early computer graphics art videos, created by combining DeFanti's GRASS system on a PDP-11 and the Sandin Image Processor. The video *Spiral PTL* (1980) was included in the inaugural collection of video art at the Museum of Modern Art.
- Computer artist Larry Cuba spent time at EVL, using the tools there for his films *3/78* and *Calculated Movements*, as well as a short special effects sequence for Star Wars.
- In 1996, EVL installed the first publicly accessible CAVE at the Ars Electronica Center in Austria, and presented a number of virtual reality artworks.

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[1] From the EVL Wikipedia page at https://en.wikipedia.org/wiki/Electronic_Visualization_Laboratory

## University of Pennsylvania

**Norman Badler** received his PhD at the University of Toronto. He joined the faculty of the University of Pennsylvania in 1974, and started the Computer Graphics Research Laboratory in the Computer and Information Science Department (in 1994 the lab became the Center for Human Modeling and Simulation). Research focused on his research emphasis on human figure animation, including human figure modeling, manipulation, and animation control, embodied agents, intuitive user interfaces, and computational connections between language and action. An early contribution with Maxine Brown and Steve Smoliar was in the area of *Laban Notation* scripting for animation. The lab achieved international recognition for its research and specifically for the *Jack software* (later marketed as a commercial product by Engineering Animation, Inc.).

Jack provided a 3-D interactive environment for controlling articulated figures. With his human-like ability to reach and grasp as well as detect and avoid "collisions" with objects in his virtual environment, Jack could be animated to perform a variety of tasks that engineers could observe and evaluate. Jack featured a detailed human model who behaved realistically in various virtual environments. Designers could test the reach, range of motion, and other features of any size human, as he or she would fit within a designed space. For example, engineers would use Jack to determine whether crucial instruments within an aircraft cockpit fall within comfortable reach of the pilot, thus saving time and expense in building prototypes.

Scene from the Jack software display

L. Weber, S. Smoliar, and N. Badler. "*An architecture for the simulation of human movement*." Proc. ACM National Conf., Washington, DC, Dec. 1978

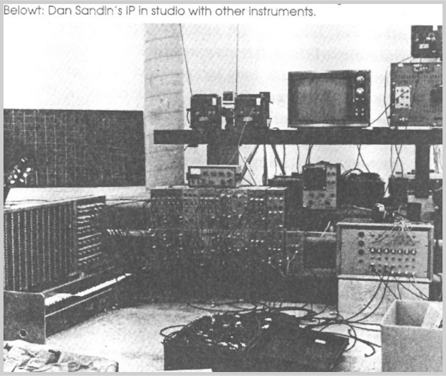
C. Phillips and N. Badler. " *Jack: A toolkit for manipulating articulated figures*." ACM SIGGRAPH Symposium on User Interface Software, Banff, Canada, October 1988, pp. 221-229.

*Simulating Humans: Computer Graphics Animation and Control*, by Norman I. Badler, Cary B. Phillips, and Bonnie Lynn Webber, Oxford University Press, Jun 17, 1993 – 270 pages

**Gallery 5.4** Circle Graphics Habitat

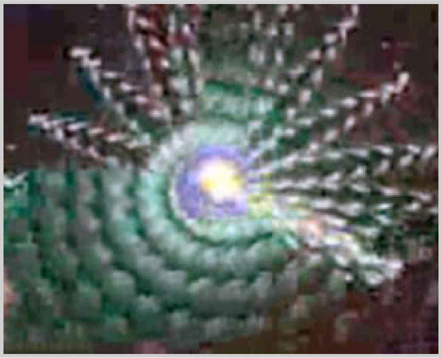
Dan Sandin and Tom DeFanti

Dan Sandin



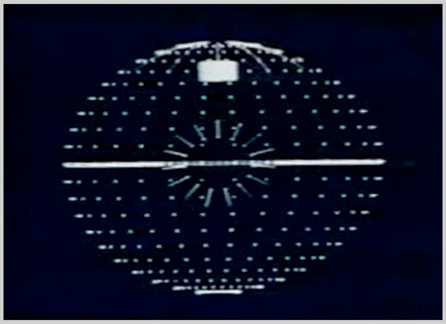
Belowt: Dan Sandin's IP in studio with other instruments.

Equipment in the DeFanti/Sandin laboratory at the Circle Graphics Habitat at the University of Illinois at Chicago Circle.Source: http://www.audiovisualizers.com/toolshak/vidsynth/sandin/sandin.htm

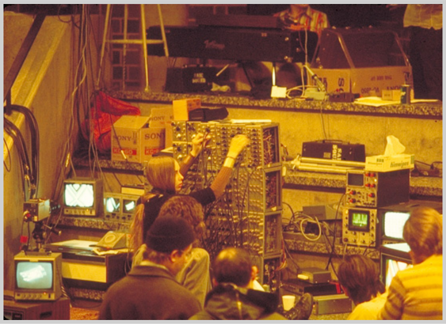


Scene from Spiral 5

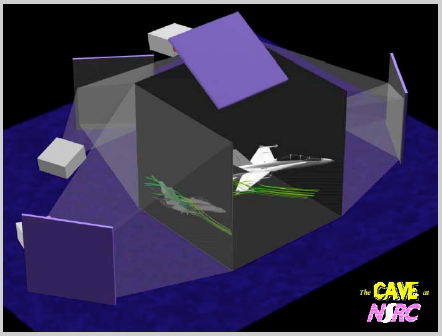
Fabricated Grass computer



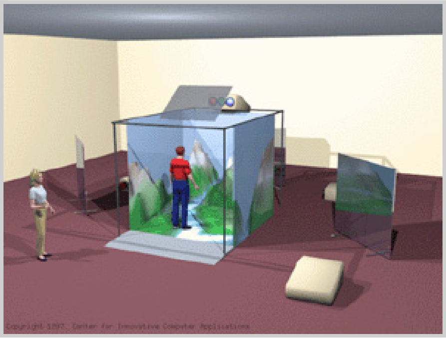
Scene from Larry Cuba's Star Wars animated sequence – 1977



Circle Graphics Habitat – 1973



A diagram of the CAVE at the National Supercomputing Research Center (NSRC). The CAVE (CAVE Automatic Virtual Environment) was developed by DeFanti, et al at the University of Illinois. This CAVE installation is an enclosed 10 feet cube room-sized advanced visualization tool that combines high-resolution, stereoscopic projection and 3D computer graphics to create the illusion of complete immersion in a virtual environment.



CAVE installed at IU

# 5.5 Other labs and NSF Technology Center

There are quite a number of other universities that also contributed to the advancement of the discipline at this point. For example, these three programs were major contributors to the discipline.

## Hiroshima University

Eichachiro Nakamae and his group at the EML at Hiroshima University in Japan conducted research on lighting and atmospheric scattering of light. Eichachiro Nakamae later became chairman of Sanei Co. and an honorary professor of Hiroshima University. He was appointed as a researcher associate at Hiroshima University in 1956, a professor from 1968 to 1992 and an associate researcher at Clarkson College of Technology, Potsdam, NY, from 1973 to 1974.

Eichachiro Nakamae

## Carnegie Mellon University

The appointment of Charles Eastman in 1968 to the faculty of what were then the Departments of Architecture and Computer Science at Carnegie Mellon University initiated a series of research projects that were seminal to the field of computer-aided architectural design. Eastman, at the Institute for Physical Planning at Carnegie Mellon, developing the GLIDE system with Max Henrion and the General Space Planner (GSP) System, a software system for solving space planning problems. Eastman and Kevin Weiler also published a seminal paper on the use of **Euler operators** for geometric modeling. Subsequent

Charles Eastman

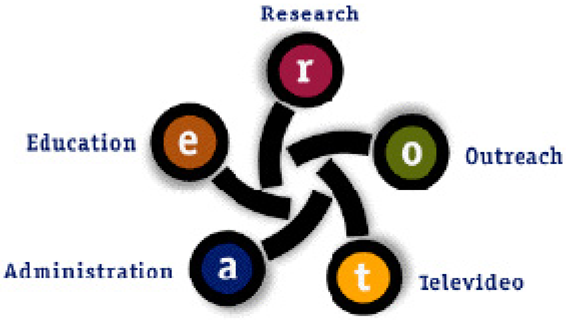
research activities concentrated on a general modeling scheme for buildings. Chris Yessios, developer of Form•Z at Ohio State, received his doctorate from this program.

## Brown University

**Andy Van Dam** created the program at Brown University, and has over 3 decades of contributions in the area of graphical user interfaces (more information on Brown can be found in the section on GUIs in Chapter 16).

Andy Van Dam

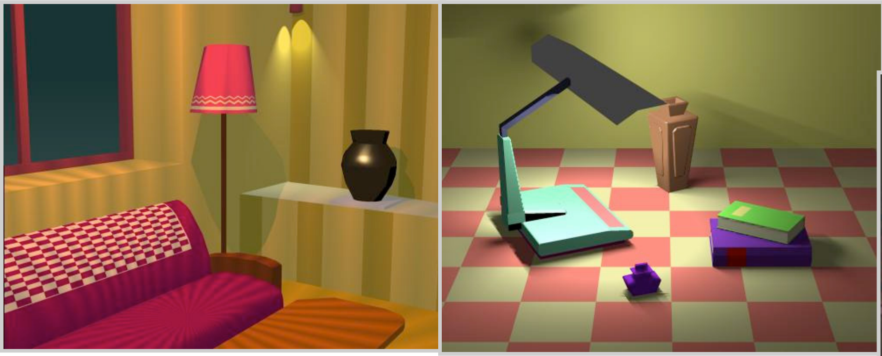
## NSF Center



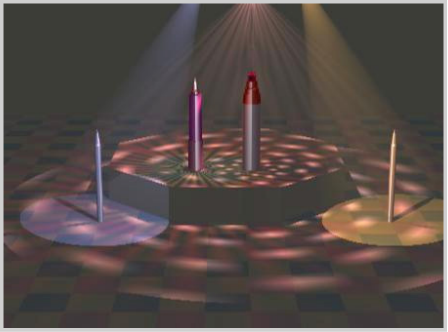
In 1991, The National Science Foundation funded the NSF Science and Technology Center for Computer Graphics and Scientific Visualization, as a consortium of five of these important universities (Cornell, Brown University, the University of North Carolina at Chapel Hill, the University of Utah, and Cal Tech).The original mission of the NSF Center, to rebuild the foundations of computer graphics, became even more important in the years after the Center was established. In addition, the center served as an experimental collaboration environment among the five universities, linked by full-time video, audio and data connections used for teaching, administration, and research. Close ties among the members influenced the research and broadened the exposure the graduate and undergraduate students at each facility, and in fact at all other academic research facilities received.

**Gallery 5.5** Hiroshima University

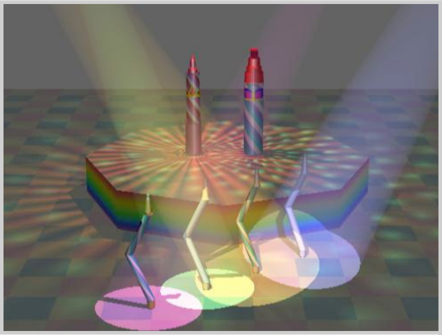
Linear light source



Light and shadows

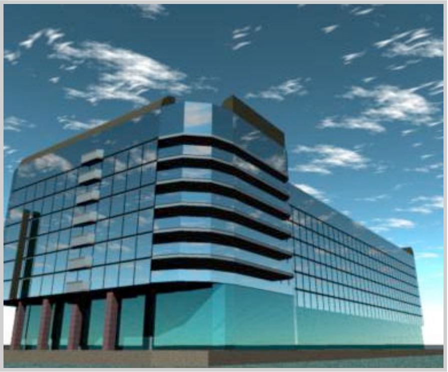


Frame from Feast of Light

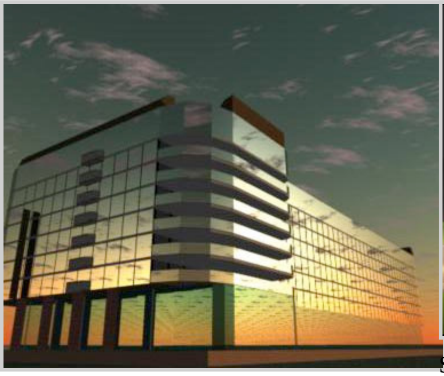


Frame from Feast of Light

Scene from Visitor on a Foggy Night



Daytime light reflections



Evening sun reflection

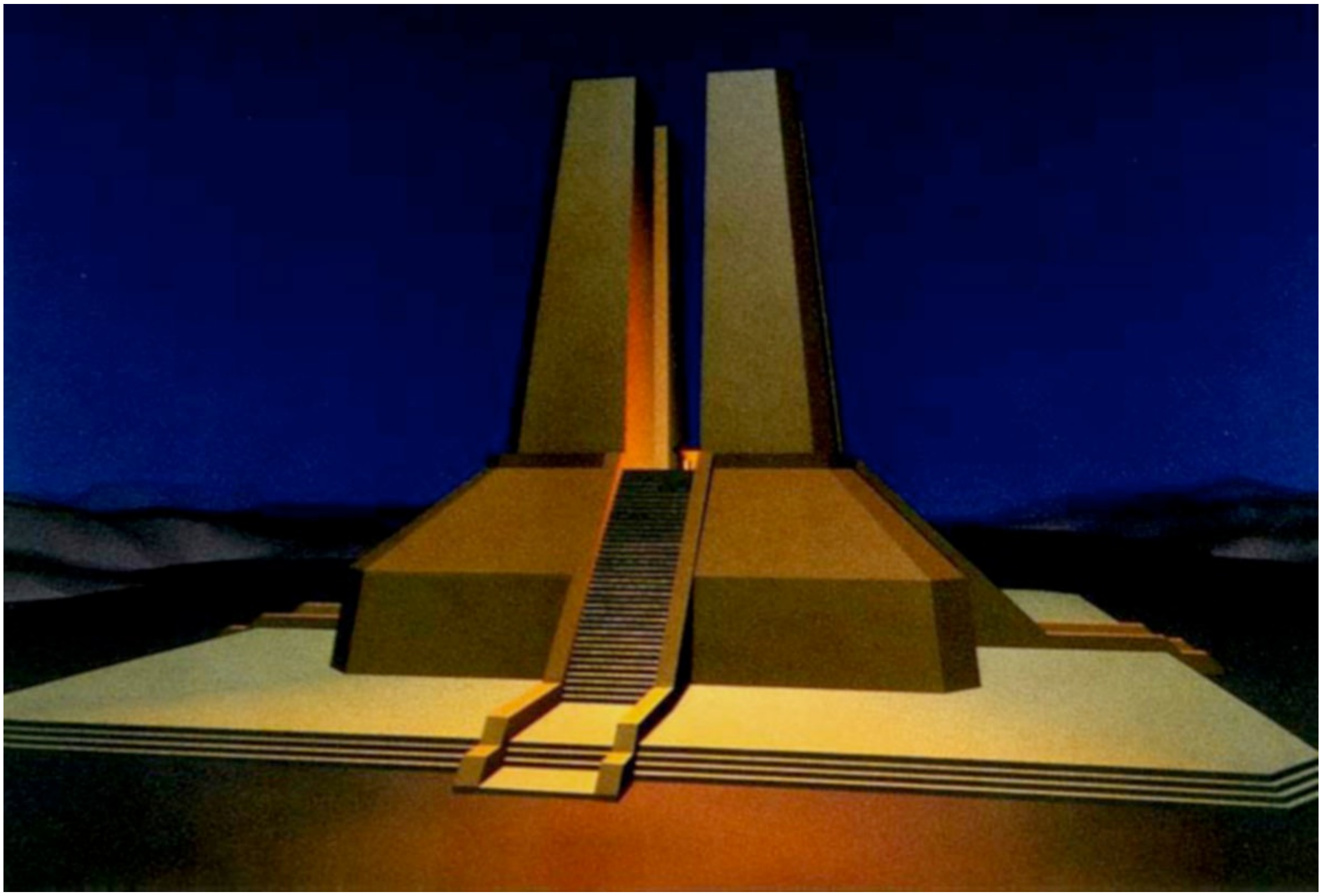
Scene from Visitor on a Foggy Night

Trees on a golf course

# Chapter 6: Commercial Companies

# Commercial Companies

After the innovative developments in the various laboratories across the country, several companies were important players in taking the technology out to the private sector, and developed graphics for visual-image hungry advertising, TV and motion pictures.



*Cray Temple, Digital Productions*

# 6.1 Digital Effects

The commercial potential for the evolving computer graphics technologies was obvious to researchers and entrepreneurs alike. First generation companies grew out of the desire to bring synthetic imagery to the television, advertising and film markets.

*Judson Rosebush (left) and Jeff Kleiser*

Founded in NYC in 1978 by **Judson Rosebush**, **Jeff Kleiser** and 5 other partners, Digital Effects was the first CG house in New York, and was one of the first companies to establish itself as a contributor to the film industry in a big way, due in part to the quality of the *Dicomed* **film recorder**. They teamed with Abel, MAGI, and Triple-I to contribute to the motion picture TRON (see Chapter 14 – they did the opening title sequence and the Bit character), but also did national advertisements and television promotions, particularly for CBS and NBC. The company closed in 1986, because of philosophical differences in the way it was to be operated (in the words of Judson Rosebush in the ACM student magazine, "…too many partners.")[1]. Rosebush later started his own company, Judson Rosebush Productions which he founded in 1986, and Jeff Kleiser became a partner in the company called Kleiser/Walzcak Construction, founded in 1987 with his partner Diana Walzcak, to create databases for CGI companies, which they located in Los Angeles and in Massachusetts.

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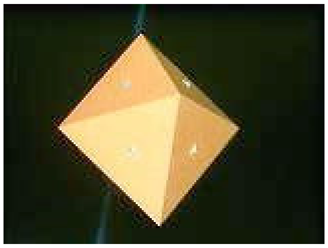
[1] DE was founded by Judson Rosebush, Jeff Kleiser, Don Leich, David Cox, Moses Weitzman, Bob Hoffman, and Jan Prins.



*The "Yes state" of the Bit character from TRON*

*The "No state" of the Bit character from TRON*

The following quote is from Jeff Kleiser, as published in *CG 101* by Terrence Masson:

> "Our original setup was a 1200-baud modem connection to an Amdahl V6 running APL in Bethesda, Maryland, using a Tektronix display to preview wireframes. (Polygons refreshed at one per second—that's one polygon per second!) The perspective data was written onto 9-track tape and was mounted on an IBM 370/158 to do scan conversion. Another tape was written as hi-con images onto 9-track and was shipped to LA for film recording on a Stromberg Carlson 4020 film recorder. Processed film was sent to NYC where I de-interlaced it onto hi-con (high contrast) film and made a print to separate out the colors and have matte rolls that I could mount on an optical printer to do multiple passes with color filters onto color negative, which was then processed and printed at Technicolor downstairs. Total time to see a color image: 1 week tops."

Equipment included a DEC PDP-11/34, the IBM 4341, a Harris 500 and 800, a proprietary frame buffer, a Mitchell full-color 24 bit camera, and a Dicomed D-48 film recorder[2]. Their software, known as *Visions*, written in the computer codes FORTRAN and APL, was proprietary to the company.

**Movie 6.1** Digital Effects 1985 Demo

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[2] Tom Sito, in his book "Moving Innovation: A History of Computer Animation" quoted DE's Judson Rosebush, recalling how DE obtained their state of the art film recorder." [The $300,000 Dicomed film recorder] had been a gift from a rich Washington-type to his mistress, who had ambitions for a career in media. We sent a truck down for it after I agreed to assume the remaining payments on the machine. Considerably less than the $300,000 it originally came for."

*Digital Effects animation showreel from 1985*
*https://youtube.com/watch?v=Mv78UsrZ07g*

Terrence Masson, *CG101*, Published by Digital Fauxtography Inc. (2007)

*http://www.cg101.com/cg101.com.html*

# 6.2 MAGI

MAGI (Mathematical Applications Group, Inc) was established in 1966 for the purpose of evaluating nuclear radiation exposure. They developed software based on the concept of ray-casting that could trace radiation from its source to its surroundings. This software, called SynthaVision (marketed by Computer Visuals, Inc.) was adapted for use in CGI by tracing light instead of radiation, making it one of the first systems to implement the later concept of ray-tracing for making images.

*Ray Tracing*

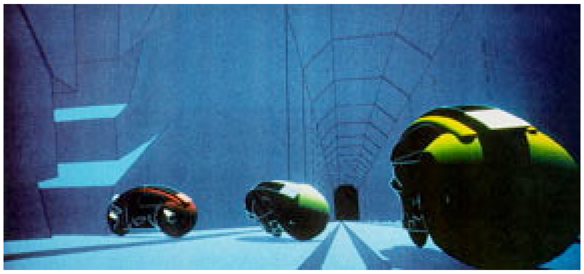
The software was a **solids modeling** system, in that the geometry was solid primitives with combinatorial operators. The combination of the solids modeling and ray tracing (later to become plane firing) made it a very robust system that could generate high quality images. The graphics side of MAGI, called MAGI/SynthaVision was started in 1972 by Robert Goldstein, with Bo Gehring and Larry Elin covering the design and film/TV interests, respectively.

MAGI did an early film test for *Close Encounters of the Third Kind*, which was recorded on a custom film recorder (4000 lines of resolution) made by **Carl Machover**. The first CGI ad is attributed to MAGI – an ad for IBM that flew 3D letters out of an office machine.

**Larry Elin** produced the company's computer animation from 1977 to 1980, when he was joined by Nancy Hunter and **Chris Wedge**. MAGI later joined with Abel, Triple-I and Digital Effects to create scenes for the movie TRON… although they did the majority of the CGI work (about 15 minutes), their most memorable contribution was the light cycle sequence.[1]

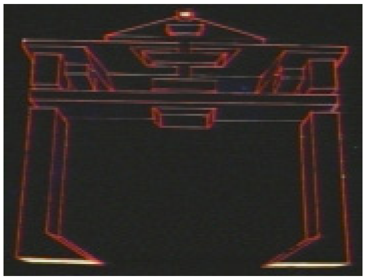
[1] The following excerpt about Larry Elin, related to the making of TRON sequences, was taken from an article on the Syracuse University website. "Being thousands of miles away from Disney's California studios was logistically difficult, as Elin had to find ways to send the

As a result of the TRON account (which totaled approximately $1.2M), more R&D was necessary, so the scientists (including key engineer **Dr. Eugene Troubetskoy**) who had been working on government contracts were brought back to visualization, and MAGI hired Ken Perlin, Gene Miller, Christine Chang and several others. On the production side, they added Tom Bisogno, Tom Miller, and Jan Carlee.



*Light Cycles*

MAGI's computer imagery occurs mostly in the first half of TRON in the Game Grid area, where they created such vehicles as the Lightcycles, Recognizers and Tanks. As mentioned above, MAGI employed the unique process of computer simulation called SynthaVision. The computer recognized the basic geometric shapes as solid objects with density. By varying the size and quantity of these shapes, MAGI constructed a limited variety of three-dimensional designs which could be easily animated. The SynthaVision process was limited in its ability to create complex objects. It was, however, very easy to create fluid motion (choreography) for these objects. Based on its strengths in motion animation, MAGI was assigned the computer imagery for the first half of the film, which consists mostly of dynamic action sequences.



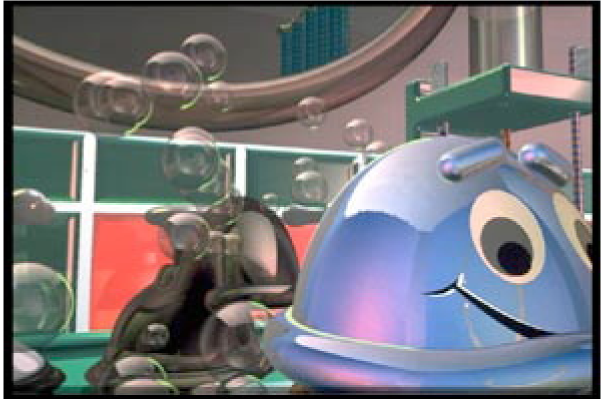
A Celco film recorder was purchased in order to efficiently output in Vistavision. After the movie, they opened an LA office in 1984 in order to capitalize on the success of the motion picture. Phil Mittelman recruited **Richard Taylor**, who supervised the effects for TRON while at Triple-I, to head this office, which closed soon after its establishment. One of the more interesting productions done at MAGI was a test for Disney (*Where the Wild Things Are* – more about the test can be seen in section 2 of Chapter 14) which used 3D scenes and camera control and 2D character animation. This test was supervised by Disney animator **John Lasseter** (now at Pixar). David Brown, who was a marketing executive with CBS/Fox Video and who later co-founded Blue Sky Studios, was brought on to head up the New York sales and production facility.

**Movie 6.2** Where the Wild Things Are Test

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/wild-things3-1.m4v

company's work across the country without the Internet. They had a computerlike machine connected to a telephone that transmitted information at roughly 1,200 bits per second — meaning that an 11-second scene could take an hour to transfer. Often, it made more sense to put the film cans on a plane to Burbank. In either case, Disney never sent anything back, and MAGI didn't get to see what the finished scenes looked like until the film premiered."

*Scenes from Dow Scrubbing Bubbles ad*



They sold to a Canadian firm, Bidmax, and the personnel dispersed to other companies and universities. In particular, Chris Wedge went to Ohio State before joining with several others to found Blue Sky Productions; Phil Mittelman established the UCLA Lab for Technology and the Arts; Larry Elin went to Syracuse University; Ken Perlin went to NYU and later won an Academy technology award for his **noise functions** in **procedural rendering** (see more about Perlin and his contributions in Chapter 19). (Note: Phil Mittelman passed away in 2000; David Brown passed away in 2003.)

Equipment included a Perkin/Elmer 3240, a Gould SEL 3287 and one of the first Celco film recorders, the Celco CPR 4000. Software was based on **combinatorial geometry** (solid modeling) using raycasting.

**Movie 6.3** MAGI Demo – 1980

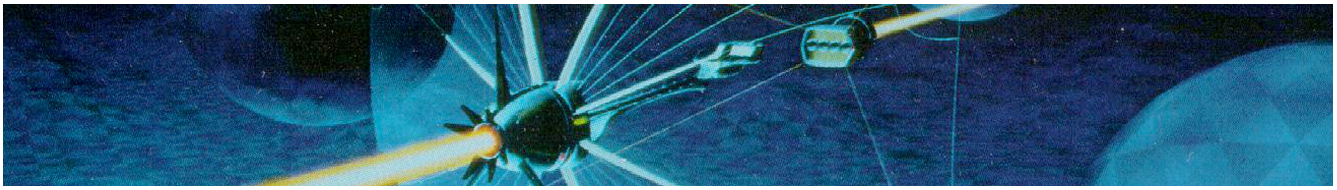
*1980 commercial demo reel from MAGI Synthavision*
*https://www.youtube.com/watch?v=lAYaX6NuI4M*

**Movie 6.4** MAGI 1982 Demo

*1982 commercial demo reel from MAGI Synthavision*
*https://www.youtube.com/watch?v=WxetroPVCl0*

**Movie 6.5** MAGI Demo (1984)
*https://www.youtube.com/watch?v=Ivk_LPQP6Ag***Movie 6.6** MAGI First Flight (1984)
*https://www.youtube.com/watch?v=EQZO1-4D0lg*

# 6.3 Information International Inc. (III, or Triple-I)



While at Cal Tech, **Gary Demos** was made aware of the work of John Whitney, Sr. who was teaching classes there, experimenting with early CG images. Whitney's work, and that of the University of Utah, prompted Demos in 1972 to go to work for Ivan Sutherland at Evans and Sutherland (see Chapter 13.) E&S used DEC PDP-11 computers along with custom E&S hardware, including the E&S Picture System and a variation of the frame buffer which was used at Utah. At E&S, Demos began discussions about filmmaking with Ivan Sutherland, and together with Glen Fleck and John Whitney Jr. they started a company in LA called the Picture/Design Group. P/DG worked on several film projects, including a test for the Carl Sagan TV show"Cosmos", and some joint projects with Information International, Inc. Founded in 1962, Triple-I was in the business of creating digital scanners and other image processing equipment.

*Mercedes logo*

*Early ABC logo*

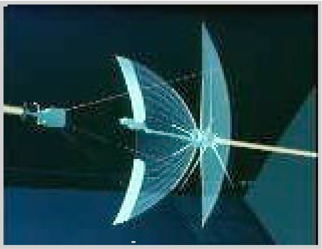
The Triple-I graphics effort was founded as the Motion Pictures Product Group by Whitney and Demos (with Art Durinski, Tom McMahon, and Karol Brandt soon joining) in 1974. Early software was written by Jim Blinn, Frank Crow, Craig Reynolds, and Larry Malone. Blinn developed software (Tranew) for Triple-I, which ran on a modified DEC PDP-10, called the **Foonly F1**, which came out of the Stanford Research group and was originally used for OCR. They did some early film tests and broadcast graphics work for the European market. Motion picture work included TRON, *Futureworld*, *Westworld*, and *Looker*. They also produced *Adam Powers, the Juggler* as a demo of their capabilities.

They marketed their services as "Digital Scene Simulation", and did several spots for Mercedes, ABC and KCET, as well as tests for scenes in *Close Encounters of the Third Kind* and an X-wing test for *Star Wars*.

Triple-I hired Richard Taylor, an art director at Robert Abel, to handle the creative director efforts there. He brought a sense of film production to Triple-I, which in his words were lacking. He directed "*Adam Powers*" and was assigned as the effects supervisor for TRON (Triple-I produced the MCP, the Solar Sailor, and Sark's Carrier). Other projects included tests for Disney's *The Black Hole* and the *Empire Strikes Back*, a stereo production called Magic Journeys, and many groundbreaking television advertising and promotion sequences.

Although they defined much of the early commercial perception of CGI, concerns regarding the computing power necessary to continue in the business prompted Whitney and Demos to leave to establish Digital Productions in 1981. They departed before TRON was completed, so much of the Triple-I contract was taken up by MAGI. Richard Taylor continued to handle the effects supervision, and was hired by MAGI when the film wrapped.

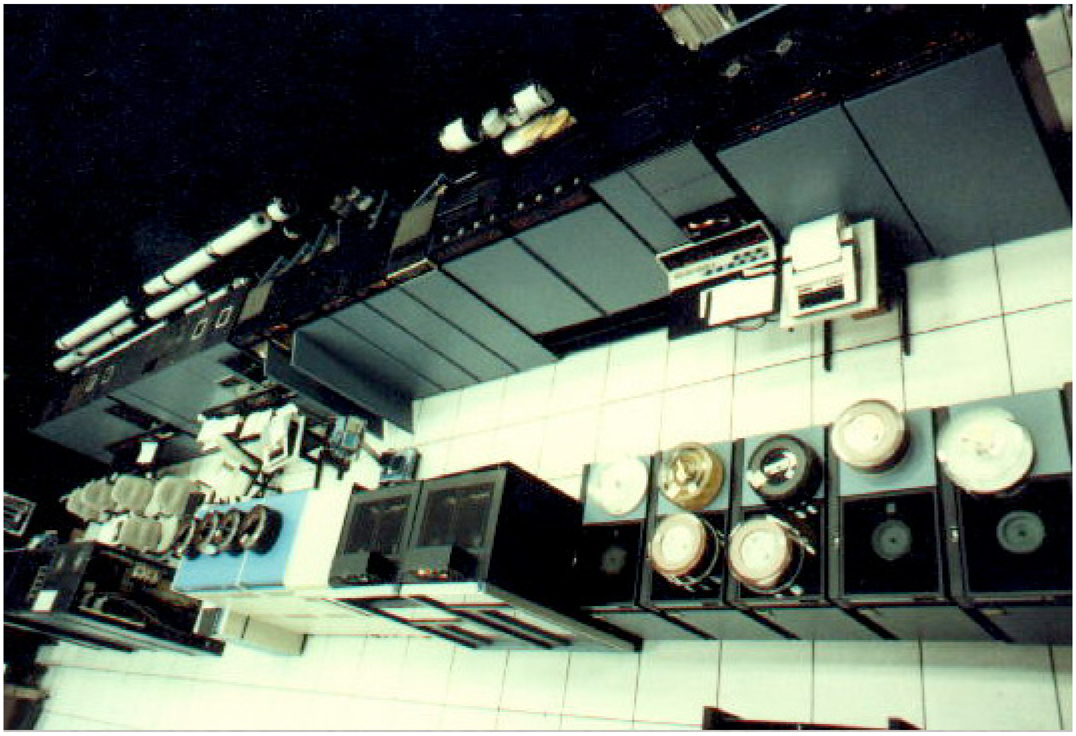
*Adam Powers – Animation (1981) at https://www.youtube.com/watch?v=GrANBKzcl_8*



Frames from TRON – Solar Sailor –

MCP

Sark's Carrier



*Foonley F1*

Equipment at Triple-I included PDP-10s, the famed *Foonley F1*[1], a proprietary 1000 line **frame buffer**, and a proprietary *PFR-80* film recorder. Software included the Tranew rendering package, developed by Jim Blinn, Frank Crow, et al, which ran on the Foonley. Animation was described using ASAS (Actor/Scriptor Animation System) developed by **Craig Reynolds**. Modeling was done on the Tektronix 4014 display using software developed by Larry Malone. The entire production process was labeled **Digital Scene Simulation**, a trade name that carried over to the new Digital Productions production company. (See the *paper* by Demos, Brown and Weinberg.)

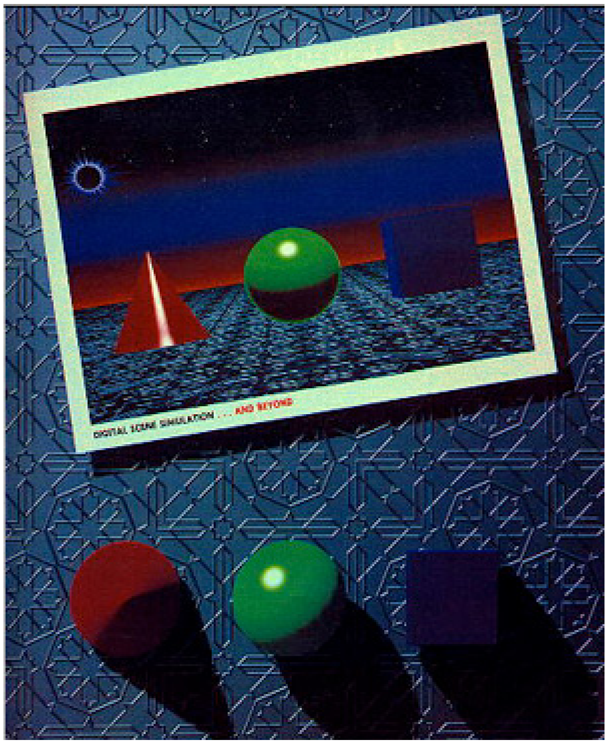
---

[1] *From the recollections of Dave Dyer, no longer available online: "Dave Poole, Phil Petit, and Jack Holloway came to Information International (Triple-I or III)] with a proposal to build an updated version of the original design (using ECL instead of TTL). I'm not quite sure how it came about - pretty crazy idea - but the connections between Triple-i and SAIL were deep and wide in those days. Triple-i was using PDP-10s for OCR, and for their groundbreaking movie group under Gary Demos and John Whitney, Jr. Triple-I had the usual grandiose plans requiring bigger and better computers. The three foonly principals spent about a year designing, constructing, and debugging the F-1. Poole was the mainstay, Petit was around quite a bit, and Holloway appeared only at crucial moments. My impression was that Triple-i paid the costs of construction and very little more - an incredible deal for Triple-i, considering that the F-1 actually worked. It would have been a very expensive boat anchor if it hadn't. I did a lot of work on the software - console computer program, a second version of the microcode assembler, and a port of TOPS-10 to run on foonly itself; and spent many fine hours with Poole, deducing I-Box bugs from errant program behavior. Shortly after the F-1 was operational, Triple-I and I parted ways and I mostly lost track of the F-1. Triple-i got out of the movie biz; the Foonly ended up following Gary Demos to several other early digital effects companies."*

*Gary Demos and the PFR-80*

For the *FutureWorld production,* the PFR (programmable film reader) had color film scanning and recording capabilities added. From this basic system, Triple-I developed what would be known as their DFP system (for digital film printer) beginning in 1978. A frame buffer was added, and the film recording and scanning became operational in 1981 after delays in the optical system development.

Gary Demos and John Whitney, Jr. went on to form Digital Productions, and later Whitney/Demos, and Demos then founded DemoGraFX (which was acquired by Dolby Laboratories in 2003), where he worked with digital TV, HDTV standards, **digital compositing**, and other high technology graphics related projects.



*Digital Scene Simulation postcard*

Whitney founded USAnimation, which later became Virtual Magic Animation, in 1992. Demos and Whitney received the Academy of Motion Picture Arts and Sciences' Scientific and Engineering Award for the Photo Realistic Simulation Of Motion Picture Photography By Means of Computer Generated Images in 1984 for work on the movies "*The Last Starfighter*" and on "*2010*" using the Cray XMP. Demos also received an Academy Scientific and Engineering Award in 1995 for Pioneering Work In Digital Film Scanning", and an Academy Technical Achievement Award in 1996 for Pioneering Work In Digital Film Compositing Systems.

**Movie 6.7** Triple-I Demo – excerpt

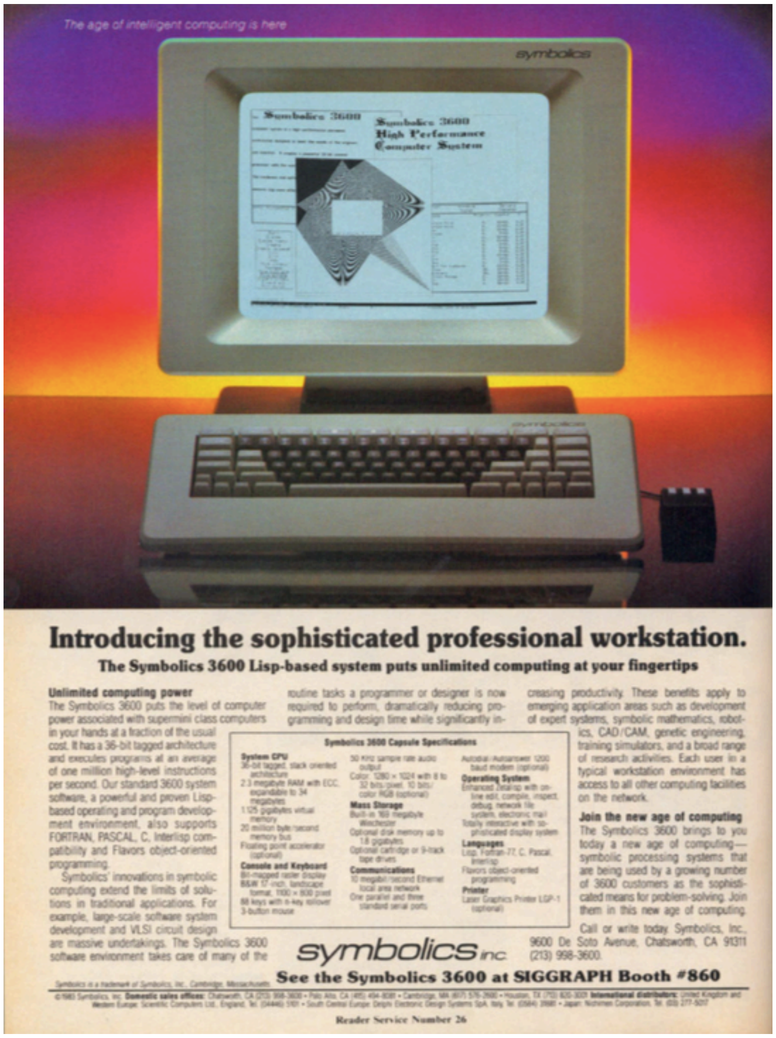
https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/tripli-i-excerpt.m4v

*Digital Scene Simulation: The Synergy of Computer Technology and Human Creativity*, by Gary Demos, Maxine D. Brown, Richard Weinberg, Proceedings of the IEEE, Volume: 72 , Issue: 1,Jan. 1984

*My personal history in the early explorations of computer graphics*, by Gary Demos. Visual Computer, Vol 21, 2005.

## Symbolics Graphics Division

Marvin Minsky and John McCarthy established the Artificial Intelligence Laboratory at MIT as part of Project MAC in the early 1960s. McCarthy's work included the development of the programming language LISP. In 1965 Minsky hired Russell Noftsker to head the lab. He and a colleague Richard Greenblatt worked together to commercialize Greenblatt's idea of a LISP workstation, and in 1980 he founded Symbolics, Inc. Their first LISP machine, the Symbolics LM-2 was released in 1981, followed soon after by the Symbolics 3600 series, which proved to be an excellent workstation for computer graphics production.



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Symbolics' innovations in symbolic computing extend the limits of solutions in traditional applications. For example, large-scale software system development and VLSI circuit design are massive undertakings. The Symbolics 3600 software environment takes care of many of the routine tasks a programmer or designer is now required to perform, dramatically reducing programming and design time while significantly increasing productivity. These benefits apply to emerging application areas such as development of expert systems, symbolic mathematics, robotics, CAD/CAM, genetic engineering, training simulators, and a broad range of research activities. Each user in a typical workstation environment has access to all other computing facilities on the network.

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36-bit tagged, stack oriented architecture
2.3 megabyte RAM with ECC, expandable to 34 megabytes
1.125 gigabytes virtual memory
20 million byte/second memory bus
Floating point accelerator (optional)

**Console and Keyboard**
Bit-mapped raster display
B&W 17-inch, landscape format, 1100 × 800 pixel
88 keys with n-key rollover
3-button mouse
50 KHz sample rate audio output
Color: 1280 × 1024 with 8 to 32 bits/pixel, 10 bits/color RGB (optional)

**Mass Storage**
Built-in 169 megabyte Winchester
Optional disk memory up to 1.8 gigabytes
Optional cartridge or 9-track tape drives

**Communications**
10 megabit/second Ethernet local area network
One parallel and three standard serial ports
Autodial/Autoanswer 1200 baud modem (optional)

**Operating System**
Enhanced Zetalisp with on-line edit, compile, inspect, debug, network file system, electronic mail
Totally interactive with sophisticated display system

**Languages**
Lisp, Fortran-77, C, Pascal, Interlisp
Flavors object-oriented programming

**Printer**
Laser Graphics Printer LGP-1 (optional)

symbolics inc

**See the Symbolics 3600 at SIGGRAPH Booth #860**

Reader Service Number 26

*Symbolics 3600 Ad*

Shortly after the introduction of the LM-2 workstation, the Triple-I graphics division ceased to operate, and several of the key employees joined Symbolics as the Symbolics Graphics Division.

Included in this group were Tom McMahon, Larry Malone, Craig Reynolds Larry Stein, Matt Elson, Bob Coyne, and others. Out of the southern California shop, the group developed software and hardware built around the LISP architecture. The major contribution to the CGI world was a line of bit-mapped graphics color video interfaces and the very powerful S-Graphics software suite (S-Paint, S-Geometry, S-Dynamics, S-Render) for Symbolics Genera operating system.

The S-Graphics software was used in the production of several notable films, including *Stanley and Stella in: Breaking the Ice* (1987), *The Little Death* (1989), *Ductile Flow*, presented at SIGGRAPH 90, *Jetsons: The Movie* (1990), *Virtually Yours* (1991), and 3D animation of the Orca whale for *Free Willy* (1993).

Symbolics workstations were the first computers capable of processing HDTV quality video, which enjoyed a popular following in Japan. As a result of the capabilities of the computers, Symbolics entered an agreement with a Japanese trading company, Nichimen. The Graphics Division was later sold to Nichimen in the early 1990s, and the S-Graphics software was ported to Franz Allegro Common Lisp on SGI and PC computers running Windows NT. It was later integrated into the Mirai software platform by Izware LLC, and has been used in movies, such as New Line Cinema's *Lord of the Rings*, video games, and military simulations.

The Symbolic's 3600 series computers were also used as the first front end "controller" computers for the Connection Machine massively parallel computers manufactured by Thinking Machines Inc. (see the section on Karl Sims in Chapter 19).

**Movie 6.8** The Little Death

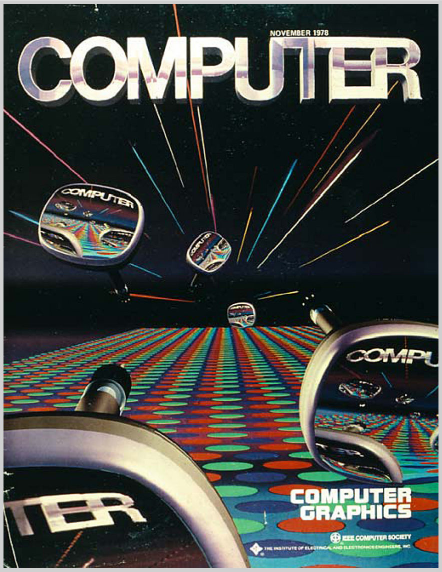
*Produced on Symbolics, by Matt Elson*
*https://www.youtube.com/watch?v=rLGRSOfnnUM*

**Movie 6.9** Virtually Yours

*From The Mind's Eye compilation #7*
*https://www.youtube.com/watch?v=BdTGJChDKrM*

> The Symbolics 3600 with the standard black-and-white monitor made a cameo appearance in the movie *Real Genius*. The company was also referenced in Michael Crichton's novel *Jurassic Park*.

**Gallery 6.1** Triple-I Images

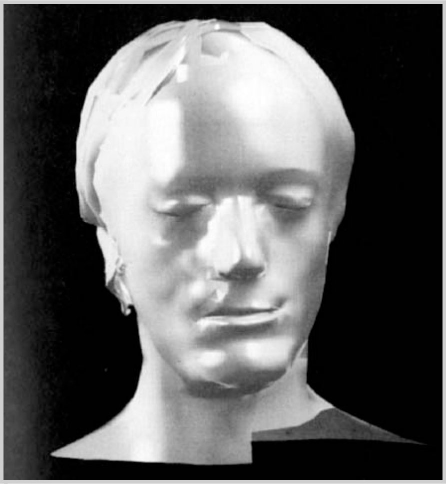


Cover of November 1978 IEEE Computer magazine.

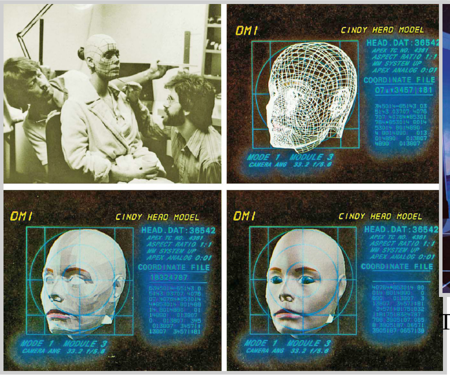
964 G. Demos

**Fig. 2.** Cover of Computer Pictures magazine, August 1980, copyright 1980 Information International

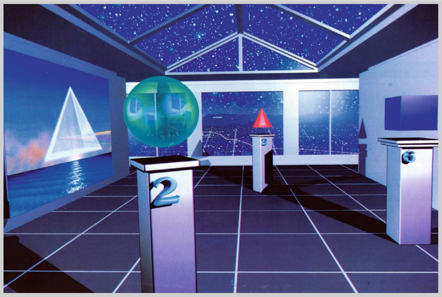
August 1980 cover of Computer Pictures trade magazine



Digitized head of Peter Fonda, for the movie FutureWorld (1976)

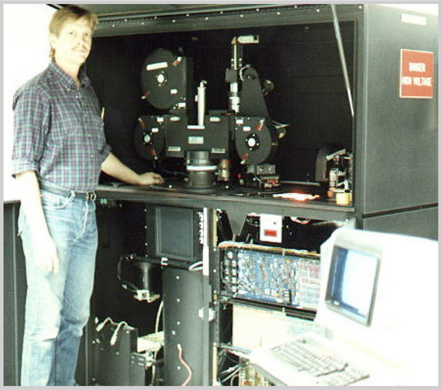


Cindy's head from the movie Looker (1980). Actress Susan Dey is digitized from reference lines by Art Durinski and Larry Malone.



Triple-I Museum (1979)

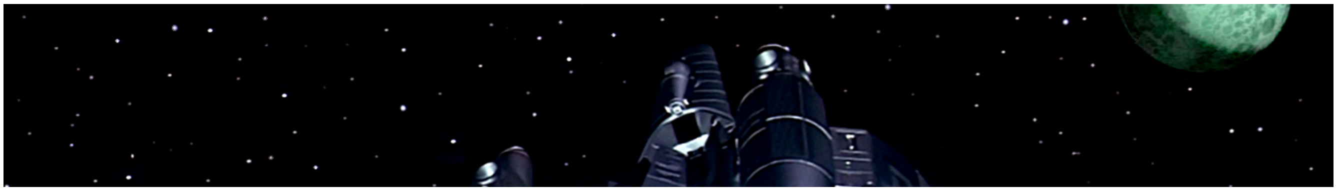
Color fringing adds to visual realism (1978)

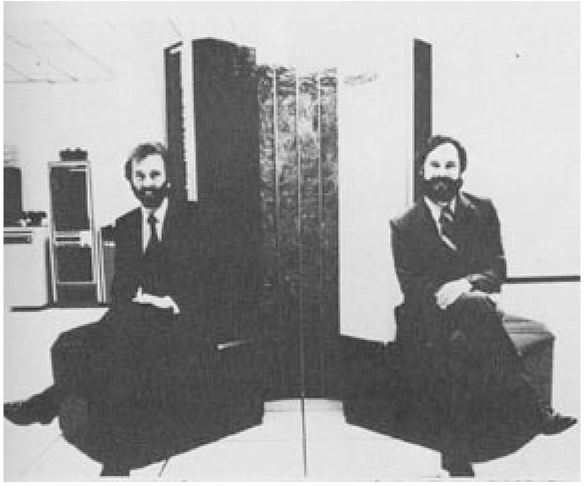


David Keller is shown here with the Digital Film Printer, developed by Gary Demos while at Triple-I.

Cover of the August, 1979 IEEE Computer Magazine. Gary Demos produced this X-wing fighter image to convince George Lucas that CG could be used to make images for Star Wars.

# 6.4 Digital Productions (DP)





*Gary Demos and John Whitney, Jr. sitting at the Cray computer*

Digital Productions was started by John Whitney, Jr. and **Gary Demos** in 1981, after they left Triple-I because of a disagreement over the amount of computing power that needed to be devoted to feature film production, particularly for the movie TRON. DP was financed by Control Data Corporation, and the Cray 1S was leased from Ramtek, the frame buffer company.

Their ultimate goal was to emphasize "high scene complexity and computational efficiency" with a focus on "large scale simulated special effects production", particularly for the motion picture industry. Key employees in the company were Elsa Granville (HR), Larry Yaeger (VP of Software), Craig Upson, Steve Williams, David Ruhoff, Jim Rygiel, Brad Degraf (Head of Production), Producers Nancy St. John and Sherry McKenna, Jim Rapley, Art Durinski, and others. At their peak, DP employed between 75 and 100 employees, and executed special effects for a number of films and advertisements.

Although the Cray provided DP with the computing power that Whitney/Demos desired, it was at a great price… one trade publication indicated that in addition to the cost of the lease, it required approximately $12,000 per month for electricity, and approximately $50,000 in maintenance. Many in the industry claimed that this kind of expense could not be justified by the kinds of contracts that existed in the effects industry at the time, but Whitney and Demos persisted.

Some of the more notable projects include 250 scenes and 27 minutes of CGI for summer 1984's *The Last Starfighter* (which cost $14M – DP's contract was for $4.5M – and grossed only $21M), Mick Jagger's Hard Woman music video, *Labyrinth*, and the Jupiter sequence for *2010*, the sequel to 2001. DP also worked on some fairly famous and notable ads and TV promotions, including AT&T (with designer Saul Bass), Pontiac, Mercedes-Benz, the Chevrolet Astro Van, and STP. **Brad DeGraf** created a connection for "Waldo" (from a sci-fi book by Robert Heinlein in the 40s), the digital puppet used by Henson Productions, to integrate motion activities in a real time sense (some argue that this was the birth of motion capture). Keeping the *Digital Scene Simulation* process developed at Triple-I, they expanded the software to take advantage of the supercomputer architecture.

*Gunstar*

*Cray XMP Supercomputer*

Equipment included E&S Picture Systems used for modeling, IMI vector graphics displays for defining and pre-visualizing the animation, and the Ramtek framebuffers used for raster display. Images were calculated and filmed at 2000×2560, and were recorded on the modified PFR at speeds that could reach 12 seconds per image, due to a fast interface to the Cray (note: the Cray 1S was replaced by the Cray XMP in 1983.). Some excess Cray cycles were sold to companies such as General Motors and Ford Motor for their own use.

In late 1984 or early 1985, the expenses of running the company, including the high cost of running the Cray, resulted in the need to discontinue the lease on the Cray, and DP was forced to purchase it outright for $17M. Later in 1985, CDC and Ramtek were both suffering financial woes, and they began to look for ways to get out of the movie making business.

In June of 1986, they agreed to terms, and DP was bought in a hostile takeover by Omnibus Computer Graphics from Canada. Whitney and Demos sued Ramtek for part of the sale proceeds, and were subsequently locked out of their offices in July and a counter suit was filed alleging that W/D started a competing company (Whitney/Demos Productions) and hired away employees. Omnibus changed the Digital Scene Simulation concept to Omnibus Simulation. They also took over Able and Associates that year, and the entire venture fell apart in 1987. (See the discussion in the Omnibus coverage below.)

**Whitney/Demos Productions**

Demos and Whitney, Jr. started Whitney/Demos Productions after the Omnibus takeover in 1986. They built the company around the Thinking Machine CM-2 and Symbolics workstations. Programming was done in LISP. One of the premiere pieces that was produced was the movie Stanley and Stella: Breaking the Ice , produced with Craig Reynolds of Symbolics, Philippe Bergeron and others. Key employees included Karl Sims, Karol Brandt, Michael Whitney, Mary Ann Morris, David Ruhoff and others. They also had a T.V contract for promotional material for CBS. In 1988 Whitney reorganized the company into USAnimation and Demos founded DemoGraFX.

In 1985, Gary Demos received his first Scientific and Engineering Award by the Academy for Motion Pictures Arts and Sciences (with John Whitney, Jr.) for the practical simulation of motion picture photography by means of computer-generated images (1984 work). In 1995, Demos was awarded his second Scientific and Engineering Award (with Dan Cameron, David DiFrancesco, Gary Starkweather and Scott Squires) for his groundbreaking work in the field of film input scanning. In 1996, the Academy honored him with a Technical Achievement Award (with David Ruhoff, Dan Cameron and Michelle Feraud) for efforts in the creation of the Digital Productions Digital Film Compositing System (the famed DFP). In 2006, Demos was awarded the Gordon E. Sawyer Award, "presented to an individual in the motion picture industry whose technological contributions have brought credit to the industry."

DemoGraFX President, Gary Demos accepting his
1995 Academy of Motion Picture Arts And Sciences Engineering Award
for his pioneering work in digital film scanning.

*Gary Demos accepts 1995 Oscar for the development of the PFR*

From the DP page of the *People Behind the Pixels: History of Computer Graphics* website:

> "DP's first major computer graphic project was for The Last Starfighter, $4.5 million worth of state-of-the-art high resolution CG animation. Beginning in Oct 83, Digital Productions traded in the 'older'? Cray-1S for the very first Cray X-MP supercomputer.
>
> The Cray was fronted by a VAX 11/780 and was used to produce nearly 300 shots totaling 25 minutes of screen time. The team used E&S PS400's for modeling and IMI vector motion systems for motion preview with Ramtek frame buffers for display. When Triple-I had wrapped the TRON work and decided not to continue in the CG film business, DP leased the Digital Film Printer (DFP) and hooked it up to on of the high speed channels of the Cray. The Cray driven DFP could scan 35mm film at four seconds a frame, and film out the 2000×2560 rendered images at twelve seconds a frame.
>
> For the first time, highly detailed computer generated images were integrated with live action as realistic scene elements, rather than as monitor graphics or deliberately 'CG' looking images. Gary Demos from the very beginning always had the drive to only produce the highest resolution, highest quality imagery possible. Kevin Rafferty(ILM) led the team that digitally encoded (modeled) many of the forms designed for the film by Ron Cobb. The technique used was to have top, front and side views of the model drawn orthographically on blueprint-like paper. A mouse/cursor (or puck?) with cross hairs would then be used to input the lines of the drawing, one point at a time. Details even included little 3D digital stunt actors inside the Gunstar cockpit."

*My personal history in the early explorations of computer graphics*, by Gary Demos. Visual Computer, Vol 21, 2005.

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(006)

*1984 Ad from Computer Pictures Magazine*

**Movie 6.10**

*1984 Demo Reel*

**Movie 6.11**

*Humantech Ad (1986)*

**Movie 6.12**

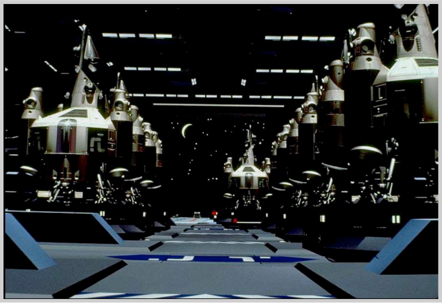
*Scenes from The Last Starfighter*

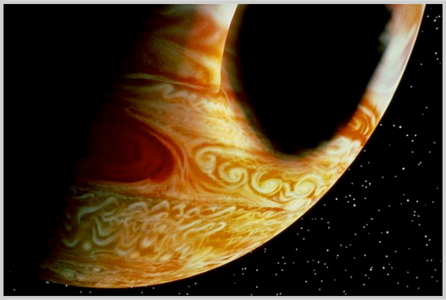
**Movie 6.13**

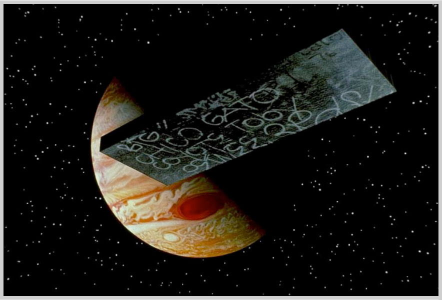
*Mick Jagger's Hard Woman – 1985*

**Gallery 6.2** Digital Productions Image Collection


?X-wing fighter from The Last Starfighter

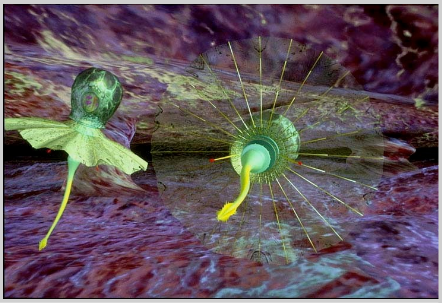

?Scene from The Last Starfighter

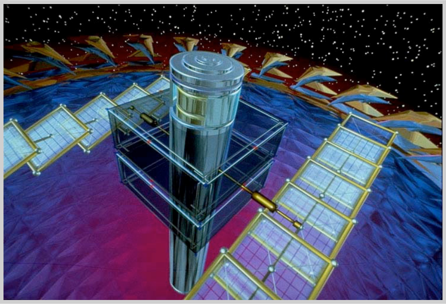

Scene from the Jupiter sequence from the movie 2010


Scene from the Jupiter sequence from the movie 2010

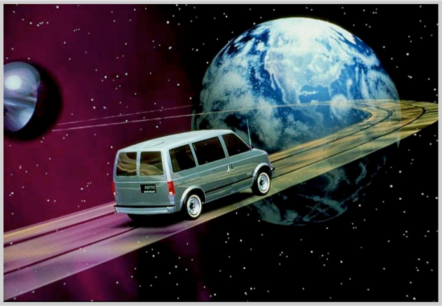
Scene from Labyrinth

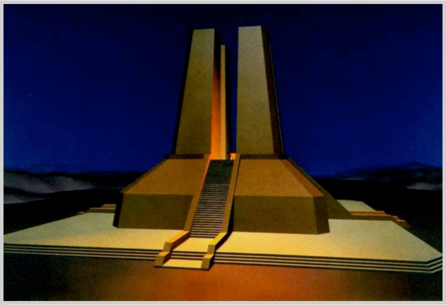

Scene from Hard Woman music video





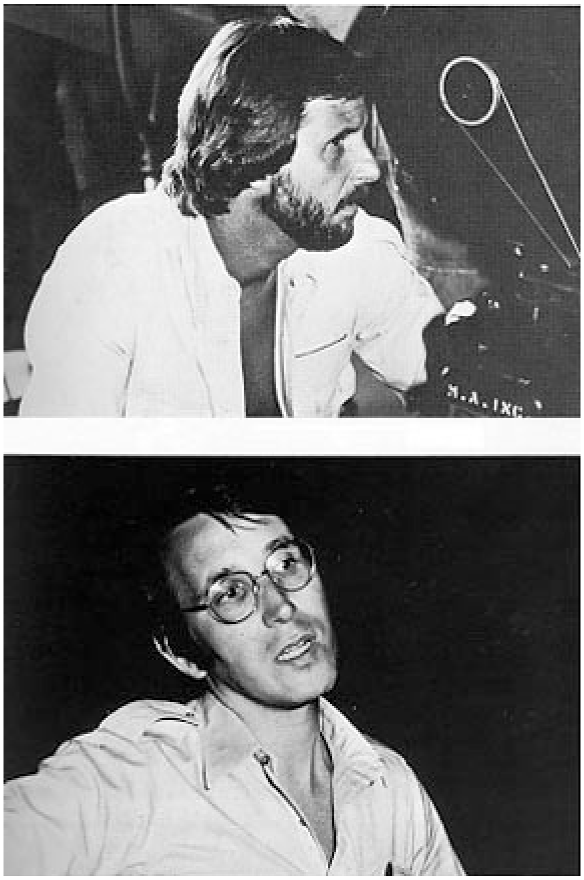

Scene from Pontiac commercial


Scene from Dodge commercial


Cray Temple, Digital Productions

Texture mask tests

# 6.5 Robert Abel and Associates



*Bob Abel (top) and Bill Kovacs*

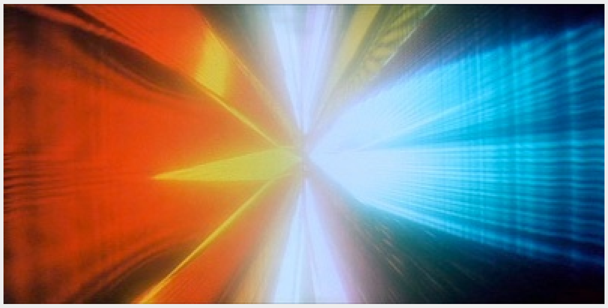
**Robert Abel & Associates** was founded in 1971 by Bob Abel, with his friend and collaborator Con Pederson. Abel had done early film work with famous designer **Saul Bass** and camera work with John Whitney, who was working with Bass on titles for Hitchcock's *Vertigo*. After touring with several rock bands documenting their concerts, Abel joined Pederson to adapt the camera system used for the movie *2001* to general film effects work, particularly for the ABC television network, in conjunction with **Harry Marks**. ?Early expertise was in multiple stop motion photography rigs and special film effects layouts. At one point Abel & Associates employed nine horizontal motion control tracks, several 360 degree motion-controlled boom arms, **optical printers**, front and rear projection systems, and vector and raster graphics systems.

Abel did early innovative work in film effects, including creative use of **slit-scan** and film streaking, including a process perfected by Richard Taylor that was dubbed the “candy-apple neon” look used in famous spots for 7-Up and Levis.

*Scene from 7-Up commercial*

The company later developed sophisticated pre-visualization vector graphics tools, using the Evans and Sutherland (E&S) PS2 graphics display. **Bill Kovacs** pushed this technology further, and created some outstanding graphics filmed directly from the vector device using vector fill approaches, including the notable Panasonic Glider animation, ads for TRW, and the The Black Hole test for Disney, which was used for the opening sequence of the movie.

Originally used in static photography to achieve blurriness or streakiness, ***slit-scan*** was perfected for the creation of spectacular animations. It enables the cinematographer to create a psychedelic flow of colors. It was adapted for film by Douglas Trumbull during the production of Stanley Kubrick’s *2001: A Space Odyssey* and used extensively in the “stargate” sequence.



Slit-scan is an animation created image by image. Its principle is based upon the camera’s relative movement in relation to a light source, combined with a long exposure time. The process is as follows:

1. An abstract colored design is painted on a transparent support
2. This support is set down on the glass of a backlighting table and covered with an opaque masking into which one or more slits have been carved.
3. The camera (placed high on top of a vertical ramp and de-centered in relation to the light slits) takes a single photograph while moving down the ramp. The result: at the top of the ramp, when it is far away, the camera takes a rather precise picture of the light slit. This image gets progressively bigger and eventually shifts itself out of the frame. This produces a light trail, which meets up with the edge of the screen.
4. These steps are repeated for each image, lightly peeling back the masking, which at the same time produces variation in colors as well as variation of the position of the light stream, thus creating the animation.

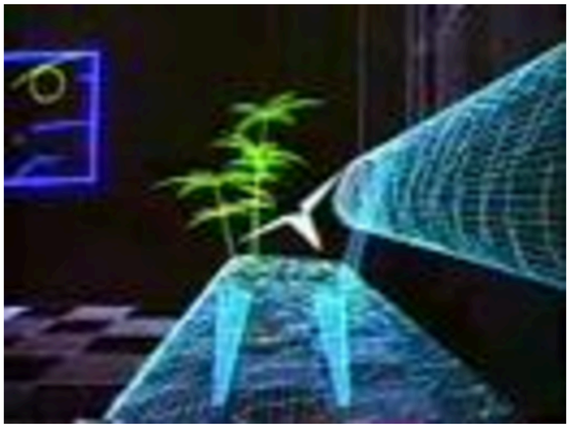
(From *http://www.rtbot.net/Slit-scan*)

A good example of a slit-scan production is this opening for ABC television at https://www.youtube.com/watch?v=rM-Vkd7On2Q

*Employees of Robert Abel and Associates (Abel is in row 3 in the center)*

Abel was one of four companies (with Triple-I, Digital Effects and MAGI) contracted to do graphics for the Disney movie TRON in 1982, after Disney worked with Abel for promotional materials and The Black Hole project.

**Movie 6.14** Panasonic Glider



*Produced by Abel in 1981, the animation was filmed directly from the screen of the E&S vector display, using colored filters* https://www.youtube.com/watch?v=3KFV0HbYULk

*Scene from Brilliance*

Abel later got heavy into raster graphics with software developed by Bill Kovacs, Roy Hall, Kim Shelly, Michael Wahrman, and others through a division called Abel Image Research. Key Abel raster work included a short demo film entitled *High Fidelity*, ads for Benson and Hedges, the *Sexy Robot* (after Fritz Lang's 1926 robot in Metropolis?), a now-famous ad titled *Brilliance*, and the opening sequence for Spielberg's *Amazing Stories* television show (*see 1985 demo reel*.)

Abel garnered multiple Clio awards (33) and had arguably the finest collection of art and technical directors in the industry. Their strength was in the ability to bring the knowledge of traditional effects work, cinematography and film making to the area of CGI. The list included "Doc" Baily, Michael Gibson, Frank Vitz, Tim McGovern, Randy Roberts, Charlie Gibson, Dale Herigstad, Richard Hollander, John Hughes, Steve Goldberg, Kenny Mirman, and others.

*Robert Abel? – Image source: Animation World Magazine*

Abel Image Research, or AIR, as it was known in the discipline, was established as a subsidiary of Abel and Associates, and was charged with developing and licensing raster software for production. Their success was limited, and the division was ultimately purchased for $1M by Wavefront, ostensibly to keep AIR from competing with the new software company.

Besides the stable of motion control and film equipment, computer graphics equipment included DEC Vax, Gould and SGI computers, Evans & Sutherland vector devices, Raster Tech frame buffers and proprietary film and recording equipment.

Some people suggest that the Abel raster software was later developed into the Wavefront Technologies product when Bill Kovacs purchased the rights to it in 1987; others dispute this, and maintain that Wavefront was developed independently, with obvious influence from the Abel software only.  Abel was acquired in October, 1986 by John Pennie of Omnibus Computer Graphics of Canada for $7.3 million.

**Movie 6.15** Excerpt from *High Fidelity*

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/hi-fi.m4v

*High Fidelity, a 1982 animation by Robert Abel and Associates to demonstrate the 3D raster capabilities of Abel Image Research (produced by Abel and Randy Roberts)*

In 1987, Omnibus defaulted on investments and closed DP, Omnibus and Abel on March 27, 1987 (called DOA day). As a result of the closure, many former Abel animators and directors left and were instrumental in starting or working for other high quality CGI companies, including Rhythm and Hues, Metrolight, Sony Imageworks, Santa Barbara Studios, Boss Films, Kroyer Films, deGraf/Wahrmann, etc. Abel went on to be an Apple Fellow, and started his own company, Synapse Technologies, and began producing two interactive multimedia projects for IBM, “Evolution” and “Revolution,” as well as a project about flight for the Smithsonian Air and Space Museum. He also was affiliated with the Center for the Digital Arts at UCLA. (Note: Bob Abel passed away in September 2001.)

VISION

On the edge of new technology, lies the beginning of imagination. Through state-of-the-art computers, We're making Raster Graphics an incredible creative tool, taking vision beyond the brink of the possible.

In best-selling interactive video games, and award-winning commercials, we've been creating raster images that get attention. And hold it.

We're proud to be on the leading edge of this new field . . . the view is just fantastic!

*

ABEL

Robert Abel & Associates

Los Angeles: (213) 462-8100 New York: (212) 758-8088 Dallas: (214) 241-4023 Chicago: (312) 580-0880

*Blow-up of actual 4 perf. frame computed at 512 lines

(004)

*Ad for Abel from 1984 Computer Pictures magazine*

**Movie 6.16** Robert Abel and Associates AT&T ad (1980)

*http://www.youtube.com/watch?v=IrnUdM_uF7s*

**Movie 6.17** Robert Abel and Associates Demo (1981)

*http://www.youtube.com/watch?v=QwpOSZeGmzw*

**Movie 6.18** Robert Abel and Associates Demo (1982)

*http://www.youtube.com/watch?v=cT3_3d2JcR0*

**Movie 6.19** Robert Abel and Associates Demo Reel (1985)

*http://www.youtube.com/watch?v=-1Yozk0g1YM*

**Movie 6.20** Robert Abel and Associates *7up Bubbles* commercial

*http://www.youtube.com/watch?v=K2U-lP-SOSQ*

**Movie 6.21** Robert Abel and Associates *Hawaiian Punch* ad (1987)

featuring music by Mark Mothersbaugh of *DEVO*

*http://www.youtube.com/watch?v=SIfh0XMrg6w*

**Movie 6.22** Robert Abel and Associates *Benson and Hedges* ad (1987)

*http://www.youtube.com/watch?v=fdBoKOpctp4*

**Movie 6.23** Robert Abel and Associates *Brilliance* ad (1983)

*http://www.youtube.com/watch?v=sCXYxNt02RI*

**Movie 6.24** The Making of Brilliance

*http://www.youtube.com/watch?v=eedXpclrKCc*

**Movie 6.25** High Fidelity
https://www.youtube.com/watch?v=WFoRJ5w2eEM

The February 2005 tribute by Ellen Wolff in VFXWorld magazine titled
*Honoring Bob Abel: VES Bestows First George Méliés Pioneer Award*
published before his posthumous Visual Effects Society honor.

> “To accomplish his goals, Abel nurtured a new generation of artists to create the studio’s string of award-winning CG spots. Kenny Mirman, who had worked on *Tron*, directed a series of innovative commercials for clients like TRW and Benson & Hedges. Mirman has likened Abel to Jedi master Obi-wan Kenobi, for the way he mentored the talent at RA&A. Bob believed “one of the things that makes us special is that we pool people’s talents,” and RA&A paired art and technical directors together in highly productive ways.”

**Excerpt from a Eulogy to Robert Abel by Kenny Mirman**

**Given at his Memorial Service on September 25, 2001**
**Read in its entirety at *https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/05/VFXPro-Abel-.pdf***

Bob's beloved family Marah and Josh, Judi, Jerry and Kirsten, and to Bob's dear friends, colleagues, students… DREAMERS.
We've lost the man carrying the torch.
The Navigator.
The one who lit the way.
Sometimes by wildfire.
Sometimes by light alone.
Sometimes by the seat of his pants.
It was Faith.

This Visionary, he was in the front, always, and his torch treated us to a view of remarkable beauty, wisdom and truth. He showed us the way, and it was magic.
Bob Abel endeared us, gifted us, inspired us, blessed us, revived us, guided us, to BE something we never thought possible…
*True to our hearts.*
Bob inspired us to not only dream, but to make our dreams reality. And he taught us by example of his passionate life. It borders on incomprehensible how Bob Abel, this man of such unspeakably passionate creative vitality and wisdom, could be taken from us so swiftly and so soon. It's an indescribable loss. Yet I have to believe it's some kind of mysterious beauty. Life's way of perfection. And so I celebrate Bob Abel's life today… this True Artist of a human being.

The one carving the path.
The Maverick. The Rebel. The Inspirer! The MythMaker. The Huckster.
The Storyteller. The Humanitarian. The Gunslinger. The Pitchman.
The Comedian. The Filmmaker. The TEACHER. The Godfather.

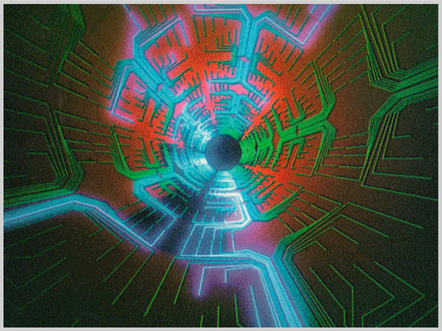
There are many more on your own list, I'm sure of it.

But one thing is certain. I bet that on all of our personal lists of "Who he was," in capital letters it says…
Bob Abel was THE VISIONARY.

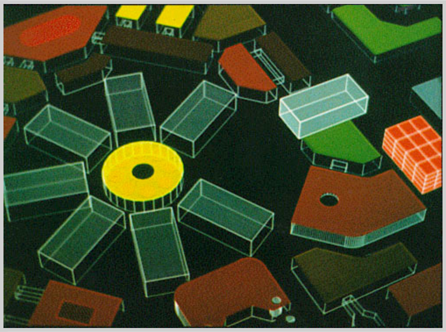
A guiding light to not only an industry, but to art, to education, and to history.
He moved us. And I miss him deeply.

**Gallery 6.3** Robert Abel & Associates Image Collection

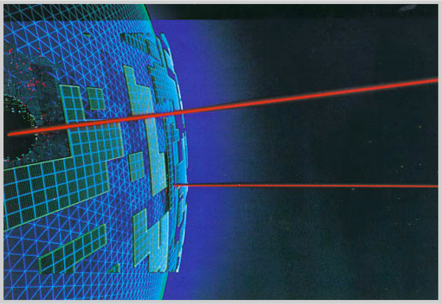
Abel logo



Vector animation from commercial for AT&T

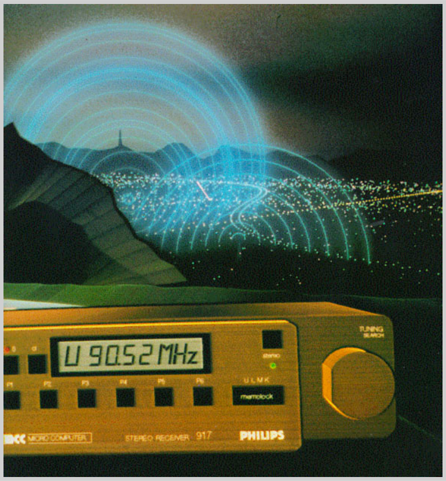


Vector animation from commercial for AT&T

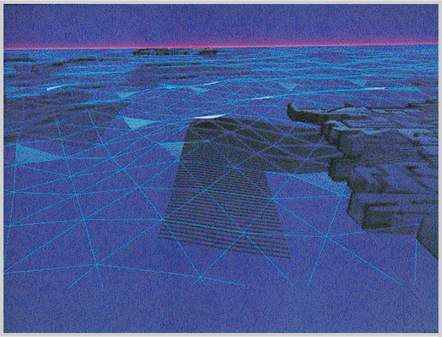


Vector animation from ad modeled after the opening for TRON

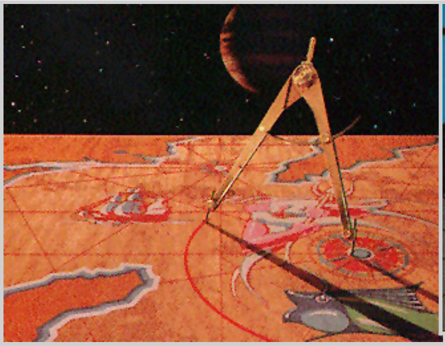
Ad for Philips



Ad for Philips

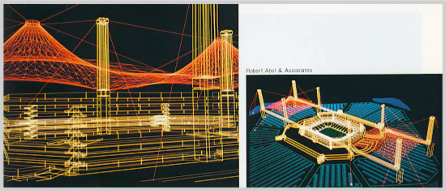


Scene from TRON

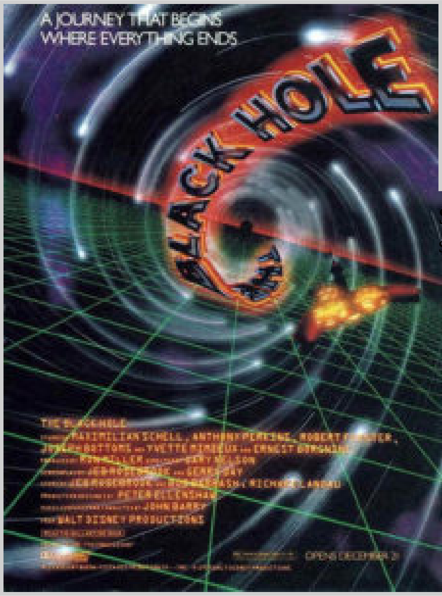


Scene from TRW ad

Scene from animation High Fidelity



Scenes from a promotional spot for a regional stadium with a movable roof structure



Poster for Black Hole

# 6.6 Cranston/Csuri Productions

In 1981, Charles Csuri approached an investor (Robert Kanuth of The Cranston Companies) to transfer the computer animation technology created in the CGRG lab at Ohio State to the commercial world, and Cranston/Csuri Productions, Inc. (C/CP) was formed.

Cranston Building, home of CCP and CGRG

It moved, along with CGRG to a Columbus facility, the former Academy for Contemporary Problems building, at 1501 Neil Avenue in Columbus. This co-location of the two organizations was important to the continuing development of each. Kanuth appointed one of his officers at The Cranston Companies, **Jim Kristoff**, as President of C/CP, and he recruited six of the CGRG researchers to join the company as a core group.

These six C/CP staff (Michael Collery, Wayne Carlson, Bob Marshall, Don Stredney, Ed Tripp, and Marc Howard) rewrote the software that was in the research lab so that it was more user-friendly and less research oriented, and added specialized utilities for character animation, procedural effects, rendering, geometric modeling and **post production**. They also expanded the capabilities of the hardware, including their proprietary frame buffers to provide tools for the growing animation staff.

C/CP animators working at framebuffers

ABC News promotion graphic – 1982

The suite of software was used to produce animation for television and advertising until C/CP went out of business in late 1987. During the tech transfer first year, Carlson reworked the modeling program DG, Julian Gomez rewrote the animation language Twixt for use at C/CP, and Stredney and Collery produced a sequence of animations that were edited together into a preliminary demonstration reel to take to potential clients. One of the first major clients was ABC News – C/CP was contracted to produce promotional graphics and openings for all 11 of the network news programs.

The strengths of C/CP were high quality image making hardware and software that was focused on the limited markets they chose to serve (television broadcast and promotion, advertising, and medical documentaries.) Production included a market-appropriate direct-to-video solution that made the production process very efficient. Exceptional sales efforts started with Kristoff and Mark Del Col, and later Scott Haines from Disney and Dobbie Schiff. They also had an effective design staff, headed by Paul Sidlo (Rezn8), that included Steve Martino, John Weber, Ronnie Chang and others.

Video technician Bob Lyon working at Ampex 1” recorder

Special purpose hardware included the Marc III and Marc IV custom frame buffers, which were designed and built by C/CP employee Marc Howard. These frame buffers provided the ability to do extended low resolution pre-visualization motion tests that were stored in frame buffer memory and played back in real time. C/CP used Vax 11/750s, 11/780s, Pyramid computers, Sun workstations, Megatek, IMI and E&S Picture Systems vector displays, and a modified Ampex Electronic Still Store (ESS), which was originally designed for slow motion replay by the television network sports industry[1]The preparation, storage, retrieval, and broadcasting of stills (slides and graphics) add up to a significant cost element that must be controlled in the operation of a typical television facility. The physical handling in using stills can damage the materials and result in human error. Furthermore, reserving a studio camera and/or a telecine chain to show stills is inefficient and not cost-effective. A new system to overcome these problems, the Electronic Still Store (ESS), has now been demonstrated by CBS and Ampex. The ESS can randomly search an electronic library of still pictures from a number of locations, arrange the stills in the order for playing, play them as fast as 1 still/s, and do these things without physically touching the media. The system

---

[1] Originally introduced in 1977 for use by CBS Sports, Ampex was awarded an Emmy for the technology. An article from the SMPTE Journal stated: "

makes available a current stock of about 1500 stills (those expected to be needed within the next 100 days) and a long-term stock of about 5000 stills. System control tasks are handled by an LSI-11 microcomputer which emulates the larger PDP-11/40. The core element of the ESS is a very reliable computer disc drive. The adaptation of the disc drive for storing PCM video requires only that the dissimilar standards of digitally encoded video and the computer peripheral be reconciled." Published in: SMPTE Journal ( Volume: 85, Issue: 8, Aug. 1976 ). Images were calculated and stored on one of several magnetic disks; the machine was programmable to facilitate the 30fps playback with a direct NTSC video output. C/CP also had a Celco 4000 film recorder, which could be used for 16mm, 35mm and 70mm motion picture film, or 35mm slide or 4×5 transparency still output.

Celco 4000 Control Panel

During the seven year period that they were in business, C/CP produced almost 800 animation projects for over 400 clients world-wide. A long-standing relationship with Roger Goodman of ABC resulted in continuous contracts for the production of graphics for ABC Sports for many years.

Key projects included: opening graphics for 3 Super Bowls; the on-air sports promotions for ABC, CBS, NBC, and ESPN networks; news opens and promos for all of ABC's news shows, as well as news opens for CBS, CBN, Fox and PBS; international network promos for ARD (Germany) CBC (Canada) ABC (Australia), Globo (Brazil) and Scottish Television; entertainment graphics for ABC, NBC, CBS, Turner, Showtime, HBO, Fox, and over 100 local affiliates; award winning ads for TRW, Sony, Proctor and Gamble, AEP, G.E., and Dow; music videos for Krokus, Twisted Sister and Chaka Khan; special projects for Goldcrest Films (The Body Machine), CoMap and the Annenberg Foundation (VISUmap animations for "For All Practical Purposes" mathematics telecourse.)

During this period, C/CP staff continued to extend the research boundaries and publish new and innovative results. Former staff members included Shaun Ho (SGI), Michael Collery (PDI), Scott Dyer (Nelvana), Jeff Light (ILM), John Berton (ILM), Susan Van Baerle (Windlight), Maria Palazzi (ACCAD), Doug Kingsbury (Lamb and Co.), John Donkin (Blue Sky), Peter Carswell (OSC), Paul Sidlo (RezN8), Jim Kristoff and Dobbie Schiff (Metrolight), Rick McKee (SGI), Jean Cunningham (PDI), John Townley and Steve Martino (click3west), Tom Longtin and many others.

In 1985 C/CP licensed their production software to Japan Computer Graphics Laboratory (JCGL) for use in the Japanese market. JCGL's president was Japanese businessman Mitsuro (Mits) Kaneko, who later became friends with Jim Kristoff.

The relationship between Kristoff and the board of C/CP cooled in late 1986 and early 1987, primarily because of Kristoff's position that an office needed to be opened in L.A. that would allow C/CP to expand into other markets. In fact, a number of former Abel employees, including Tim McGovern, Con Pederson, Neil Eskuri and "Doc" Baily, were hired and relocated to Columbus for training, ostensibly to prepare to staff an L.A. office. Kaneko and Kristoff proposed an investment strategy that would increase their control, but the funding was not available.

Kristoff resigned, and later opened Metrolight (originally to be called Northern Lights Productions) in L.A. and Wayne Carlson was named President, as Chuck Csuri had left C/CP in 1985 to return to his OSU duties at CGRG. Carlson saw the company through Chapter 11 liquidation (the software was purchased by Lamb and Company in Minneapolis), and Cranston/Csuri formally closed in October, 1987.

**Movie 6.25** Gears – NCGA Demo

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/CCP_NCGAGears-1.m4v

*Created by Tom Longtin*

**Movie 6.26** C/CP Demo (1982)
*http://www.youtube.com/watch?v=ghNjMCHyu5w*

**Movie 6.27** C/CP Demo (1983)
*http://www.youtube.com/watch?v=6EOFjHbiVMY*

**Movie 6.28** C/CP Demo (1985)
*http://www.youtube.com/watch?v=Q8TYobTi234*

**Movie 6.29** Clio Finalist Ad for TRW (1986)
*http://www.youtube.com/watch?v=GvICw-8WaGk*

**Movie 6.30** C/CP Ads Reel
*http://www.youtube.com/watch?v=8CVkBZJ_zpI*

Cranston/Csuri Productions produced over 800 animations for over 400 clients worldwide. Every major television network, including ABC, CBS, NBC, the Canadian Broadcasting Co., German ARD Television, ABC Australia, Rede Globo in Brazil, and the BBC had show openings or promotions produced at C/CP.

Cable networks, including HBO, Cinemax, The Turner Broadcasting Network, TNN, the Country Music Channel, CNN and others did the same.

Sports broadcasts were a specialty, and C/CP produced graphics and animation for CBS Sports, ABC Sports, NBC Sports, ESPN, the NFL, NFL Films, HBO and others. C/CP produced the opening for two Super Bowls, the NCAA Basketball Championships, Major League Baseball, the Breeder's Cup, Wimbledon, College Football and Basketball, and IROC Racing.

All of the major news shows used C/CP graphics, including NBC Nightly News, ABC World News Tonight, and CBS Evening News. ABC contracted for all 11 of their major news shows, and also for the United Airlines in-flight broadcast.

Advertisements included Clio nominated TRW pieces, ads for Sony, IBM, Ameritech, McDonnel Douglas, Jeep, Contac Cold Capsules, Actifed, General Electric, Pert Plus, Procter and Gamble, Always overnight pads, M&I Banks, Benjamin Moore Paints, Lowenbrau Beer, Warner Cable, and many others.

Corporate communications were done for GE, IBM, American Electric Power, Mount Carmel Health, Landor and Associates, Cranston Securities, Cranston Development, and others.

C/CP also specialized in medical animation, producing dozens of sequences for the BBC series The Body Machine. They produced over 40 segments for the Annenberg series on Mathematics for PBS. The produced a generic promotional package for local television markets, customizing it for almost 100 local stations.

They did scene tests for several motion pictures, including an unnamed movie from Disney, Flight of the Navigator,and the Brave Little Toaster.

For a complete list of the C/CP clients, go to *https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/05/CCPClients.pdf*

**Gallery 6.4** Cranston/Csuri Productions Image Collection

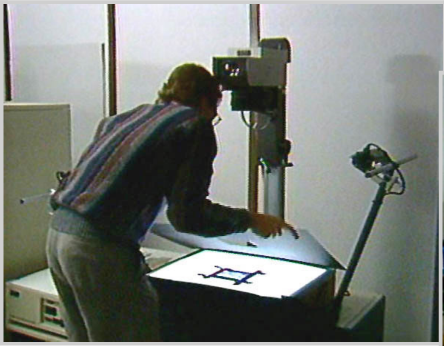
Interior lobby of the Cranston/Csuri headquarters in Columbus

Bob Lyon editing on the Ampex 1” recorders.

The CCP Ampex Electronic Still Store (ESS)

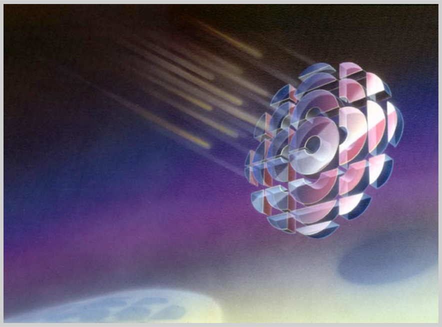
Hsuen Chung Ho working on the video playback software.

Maria Palazzi at the IMI500 Display



Steve Martino at the film capture station.

Steve Martino at the digitizing table with the Megatek display



Drawing for design of Canadian Broadcasting (produced by Bo Gehring)

ABC Fall promotion

NBC Fall Campaign

NBC Winter Olympics Show promotional graphics

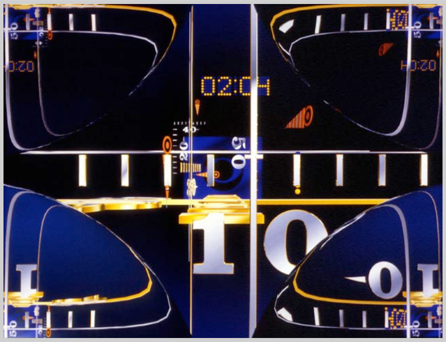
Good Morning America Show Open

PM Magazine show open

Cinemax show open

CBS Evening News Show Open

CBS Sports NFL promotion

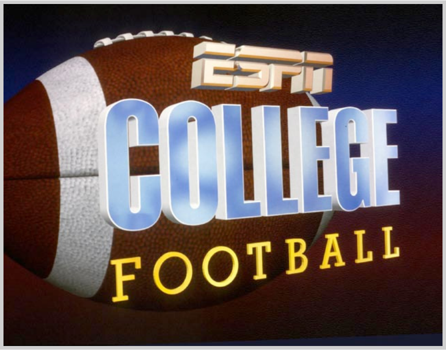


Superbowl opening graphics

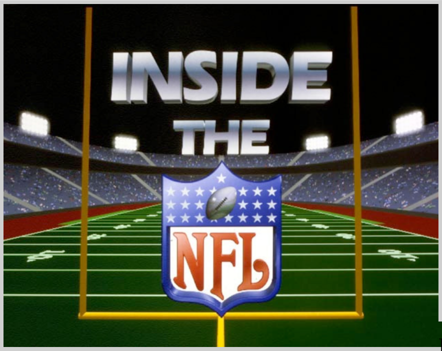
Lombardi Trophy – part of NFL SuperBowl promotion

ESPN College Basketball show open

ESPN College Basketball show open



ESPN College Football show open



Inside the NFL show open

Inside the NFL promotional graphics

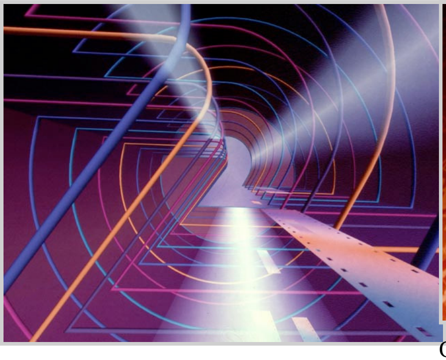
Wimbledon tournament graphics

Wimbledon tournament highlights promotion

CBS Final Four animation

NBC Breeders Cup promotional graphics

ABC affiliates promotional graphics



ABC affiliates promotional graphics –
Channel 2 in New York

Channel 4 Detroit graphics

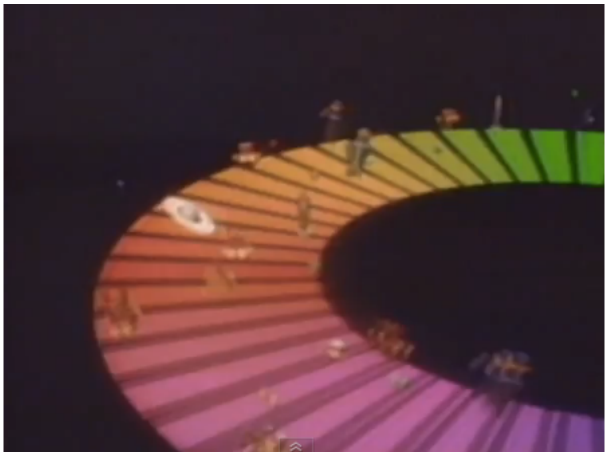
The Body Machine graphics

# 6.7 Pacific Data Images (PDI)

*PDI logo*

Pacific Data Images (PDI) was started in Los Altos, California in 1980, by **Carl Rosendahl**. He was soon joined by Richard Chuang (1981) and Glenn Entis (1982) and they moved to Sunnyvale.

Rosendahl contracted with Rede Globo in Brazil to develop software for their television promotions for the network, and designed some early show opens and specials. As a result, this helped finance the development of their software environment, which included an animation scripting language, modeling, rendering and motion design programs, all written in the C programming language. They started their production using DEC VAX systems, but were instrumental in introducing what was called the "superminicomputer" to the production world, in the form of the Ridge 32 computer. It was 2-4 times faster than the VAX 11/780 at a fraction of the cost, and its virtual memory allowed PDI to expand beyond the 2MB memory limitation of the VAXen. Much like Cranston/Csuri, PDI focused on direct to video production, as opposed to the film output that was being done at Abel and Digital Productions. While CCP used a modified Electronic Still Store (ESS), PDI modified the interface to a Sony BVH-2000 in order to do single frame recording. They also used an IMI500 for motion design.



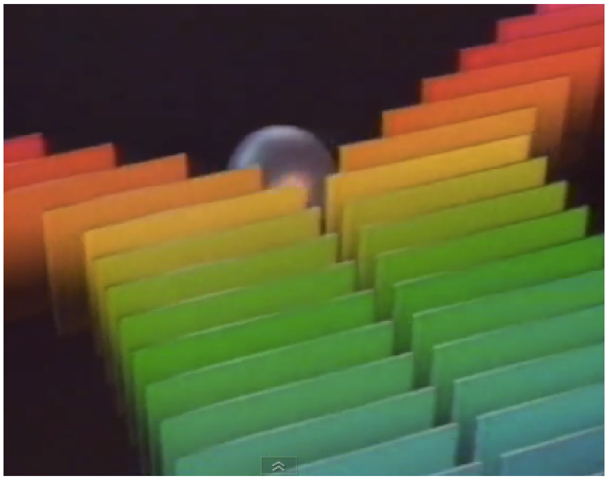
*Frame from early PDI video reel*

Carl Rosendahl

Glenn Entis

Richard Chuang

Some of the early production contracts included Globo, an Emmy award winning open for Entertainment Tonight (produced for famed promotion designer Harry Marks[1]), ABC Sports 84 Olympic promos, NBC News, the Doughboy for Pillsbury, Crest, and Bud Bowl, etc. While the early focus was on TV network productions (they captured over 50% of that market in 1985), PDI introduced the digital film scanning process in 1990, which they used to popularize automated rig removal and image touchup. They also were instrumental in introducing performance animation for theme parks, ads and movies, starting with a project (Waldo)[2] with Jim Henson Productions for a real time performance character.



*Frame from Rede Globo promotion*

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1. Harry Marks is an award-winning broadcast designer and co-founder with Richard Saul Wurman of the Technology, Education and Design (TED) Conferences,or TED talks. He was the producer for films such as *Mad Dogs and Englishmen*, and was widely known for his work with ABC television. The Monterey Herald reviewed his career in an article in 2013.
2. From the Muppet Wiki website: "Despite his CG nature, Waldo was controlled in real time by a puppeteer, making use of a mitten-like motion-capture device called a waldo (which he was named after). Jim Henson had begun experimenting with creating digital characters in the mid-1980s and Waldo's underlying technology grew out of experiments conducted to create a computer generated version of Kermit the Frog. Waldo's strength as a computer generated puppet was that he could be controlled by a single puppeteer in real-time, in concert with conventional puppets. The computer image of Waldo was mixed with the video feed of the camera focused on physical puppets so that all of the puppeteers in a scene could perform together. Afterward, in post production, he would be re-rendered in full resolution, adding a few dynamic elements on top of the performed motion. Waldo's design was led by Kirk Thatcher with input from a variety of other artists, including Timothy Young (who provided concept sketches) and animated by Pacific Data Images, later known as PDI/DreamWorks. Thatcher was greatly influenced by Chris Wedge's 1987 CG Short, *Balloon Guy*". Waldo C. Graphic was presented in Boston at SIGGRAPH. *Walters, Graham. The Story of Waldo C. Graphic. Course Notes: 3D Character Animation by Computer, ACM SIGGRAPH '89, Boston, July 1989, pp. 65-79*

Commercial popularity of morphing was helped along with a music video, *Black and White*, produced for Michael Jackson in 1990. They broke into the movie production business with contributions to such films as *Batman Forever, The Arrival, Terminator 2, Toys, Angels in the Outfield*, and produced the 1998 fully CGI hit *AntZ*. They also produced the Simpson's Halloween Special Homer in 3D in 1995.

*Frame from Entertainment Tonight show open*

*Frame from The Simpsons, Homer in 3D*

The strengths of PDI include character animation, lip synch, rendering effects, the aforementioned **rig removal** and cleanup, and **performance animation**. The industry has acknowledged that their employee-focused approach to business helped them succeed where others failed. PDI always had a history of letting their animators pursue individual projects and shorts, and they produced award winners in this category, including: *Opera Industrial (86), Chromosaurus, Cosmic Zoom and Burning Love (88), Locomotion (89), Gas Planet (92), Sleepy Guy and Bric-a-Brac (94*).

Frame from Chromosaurus

Frame from Gas Planet

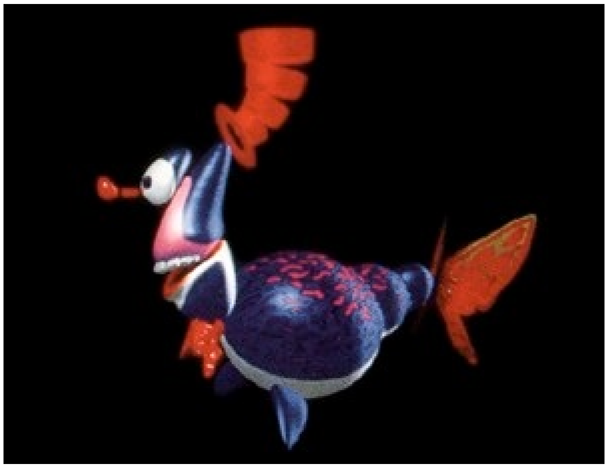
Frame from Locomotion

Entis left PDI for the game industry in 1995, joining Dreamworks Interactive (then Electronic Arts) as CEO. He earned a Scientific and Technical Award from the Academy of Motion Picture Arts and Sciences, was a founding board member of Los Angeles' Digital Coast Roundtable, and was chairman of the Academy of Interactive Arts & Sciences. Carl Rosendahl sold his interest in PDI and left in 2000 to become managing director for Mobius Venture Capital and a board member of iVAST, an MPEG4 software company, and several other Bay Area technology firms.

*PDI Headquarters*

The Academy of Motion Pictures Arts & Sciences (A.M.P.A.S.) recognized PDI's proprietary animation system with an Oscar, a technical achievement award in 1997. PDI R&D team-member, Nick Foster, was awarded a 1998 A.M.P.A.S. technical achievement certificate for his development of software tools built to simulate water and fluid.

In March 1996, PDI signed a co-production deal with DreamWorks SKG to create original computer-generated feature films, including *Antz*. In February 2000, DreamWorks acquired the majority interest in PDI to form PDI/DreamWorks. Under this union, *Shrek*, PDI's second animated feature film, hit theaters in spring 2001, and *Shrek 2* in 2004, and PDI also developed the movie *Madgascar*.

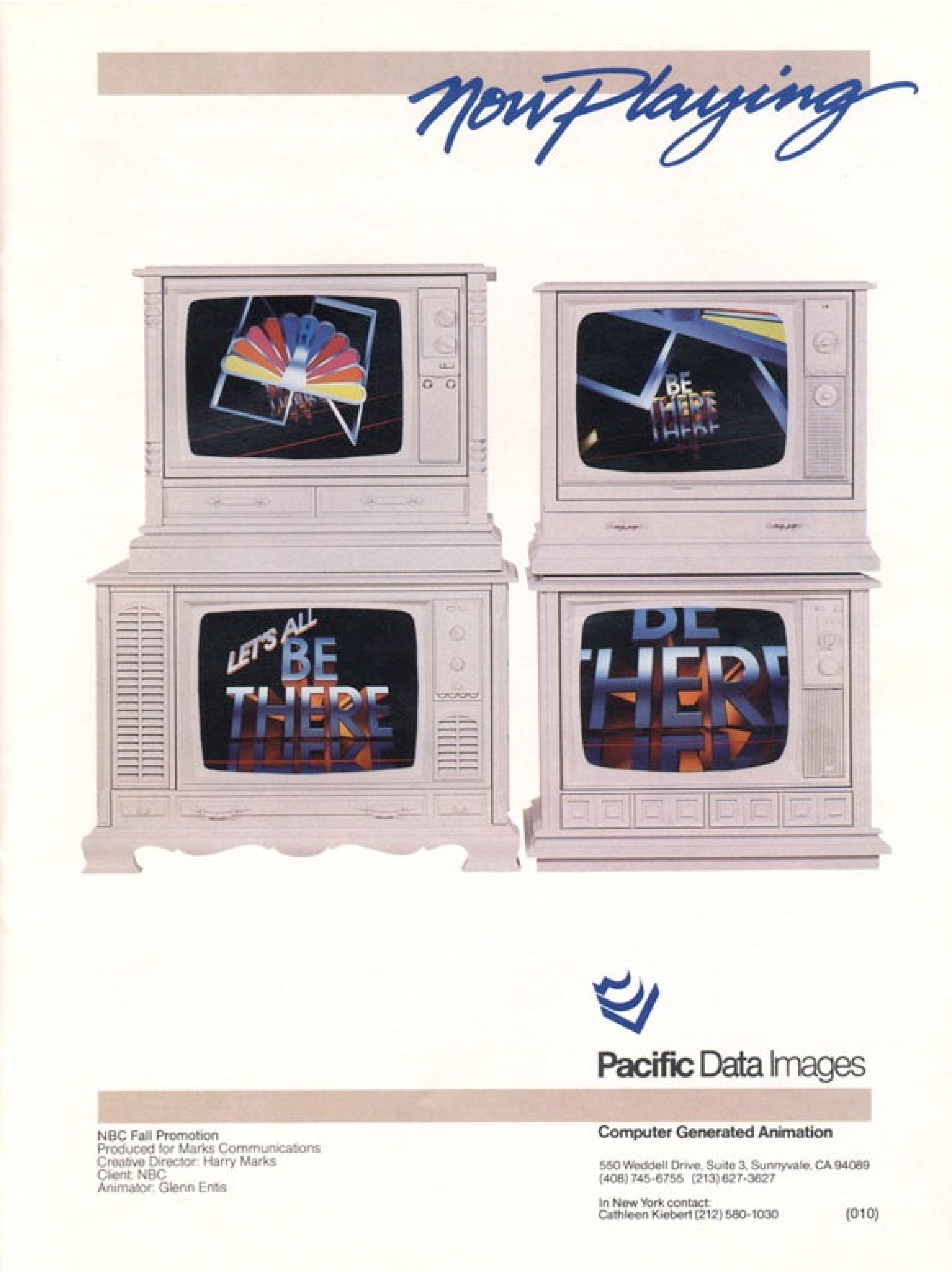


*Waldo C. Graphic, produced for Jim Henson*

*Customizable television network promotional spots were a staple for graphics production companies in the 1980s, including this PDI graphic produced for CBS*

**Movie 6.31** PDI Morphing

*Famous morphing process produced by PDI for the Michael Jackson Black or White video.*
https://www.youtube.com/watch?v=0b1_4NI3XIM



Pacific Data Images

NBC Fall Promotion
Produced for Marks Communications
Creative Director: Harry Marks
Client: NBC
Animator: Glenn Entis

**Computer Generated Animation**

550 Weddell Drive, Suite 3, Sunnyvale, CA 94089
(408) 745-6755 (213) 627-3627

In New York contact:
Cathleen Kiebert (212) 580-1030 (010)

*PDI Ad from 1984 Computer Pictures Magazine*

**Movie 6.32** Pacific Data Images demo (1983)
*https://www.youtube.com/watch?v=b0cHnFxxLC4*

**Movie 6.33** Locomotion
*http://www.youtube.com/watch?v=468W7XW4Kpg*

**Movie 6.34** Chromosaurus (1985)
*http://www.youtube.com/watch?v=HOUYSLStGak*

**Movie 6.35** Jim Henson demonstrates the Waldo system and Waldo C. Graphic
https://www.youtube.com/watch?v=dP6TUB7KQc4

**Movie 6.36** Richard Chuang presents the 25 year history (1 hour)
*http://www.youtube.com/watch?v=cQkEA62KWQQ*

In November of 1998, Pixar released their hit movie about ants, called *A Bug's Life*. But a little more than a month earlier, Dreamworks released their ants movie, called *Antz* (produced by PDI). As was often the case in the CGI world in the 1980s and 1990s, PDI and Pixar people were friends and healthy rivals, even co-sponsoring a famous party at the annual SIGGRAPH conference. So it seemed like more than coincidence that these two studios released a movie about ants at the same time. Peter Burrows of BusinessWeek writes about the ensuing controversy in his article *Antz: vs Bugs: The Inside Story of How Dreamworks Beat Pixar to the Screen* in the November 1998 issue.[3]

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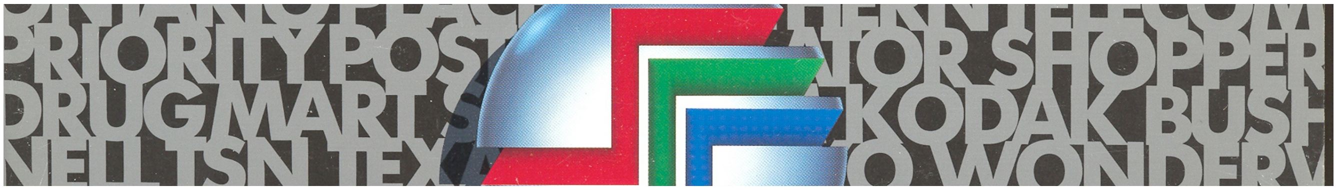
3. This article is no longer available online. It was summarized in a Wikipedia page for the movie *A Bug's Life*, with other references added. An excerpt from this summary can be viewed at *https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/09/Antz-vs-Bugs-summary.pdf*

# 6.8 Omnibus Computer Graphics



*Omnibus creative team: Keith Ballinger, Kim Davidson, Dan Philips, John Stollar (from 1986 Shareholder Report)*

Omnibus was founded in Toronto. They were originally in the business of marketing and communications, and expanded into video production. They founded Image West in Hollywood in 1975. Image West primarily used analog video for production, including the famous *Scanimate* (more about Scanimate can be found in Chapter 12.) In the late 70s, *Image West* split from Omnibus.

In 1974, they hired **John Pennie** as President, and they established Omnibus Video, Inc. in 1981 (using the NYIT Tween software), and Omnibus Computer Graphics in 1982. The produced the first CG commercial in Canada in 1983, and went public later that year.They opened an office in New York in 1984.(which was headed by George Heywood) , and in 1986 purchased Digital Productions for 800,000 shares of stock valued at $12M, and Robert Abel and Associates for $7.3M to establish a presence in Los Angeles in the film world. They also opened a Japanese facility.

Omnibus purchased the Foonly F1 from Triple-I and placed it on the Paramount lot. The investments that allowed for the takeovers of DP and Abel were in part due to predictions by Pennie that investors would see income of upwards of $55M per year. They consolidated the efforts of the three companies and initially laid off 50 people. As a result of the extremely fast expansion and alleged discrepancies in the stock offering, they accumulated a $30M debt, including losses of $5.9M in one quarter alone.[1] As a result, they closed the doors on the combined companies in October of 1987, thus closing the three CGI powerhouses in one fell swoop. Almost 150 people were affected by the closure. This became known as DOA day (Digital-Omnibus-Able).

*Canadian Broadcasting Company*

*Flight of the Navigator*

Omnibus productions (pre DP/Able) include *Explorers*, *Flight of the Navigator, Wonderworks*, and the promotion for the Vancouver Expo. The PRISMS software (funded by a grant from the Canadian government) developed at Omnibus was sold to former employees Kim Davidson and Greg Hermanovich who started SideFX Software in 1987. They currently market the Houdini software product.

The following article is from an issue of the Canadian publication *Graphics Exchange*:

***Technology Stories Your Grandfather Never Told You***

JOHN PENNIE WAS A CANADIAN BOY WITH A DREAM. He knew without a shadow of a doubt that there was a big, bright future in computer graphics, and he was determined to be part of the big boom when it happened.

In 1982 he started a company called Omnibus . By 1984, Pennie had Omnibus steam-rolling; slick annual reports and state-of-the-art computer animation studios in Toronto and Los Angeles made it easy for Pennie to dazzle heavyweight investors with high tech glitz and the promise of having a piece of the digital future.

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[1] From CG101, quoting Dave Sieg: The Omnibus management knew nothing about computer animation, but kept muttering about "Economies of Scale". The reality was: three separate sales forces, three separate production crews, three separate facilities, philosophies, software systems and hardware systems, none of which were likely to ever work together. What is ironic is that the next Star Trek movie was about to go into production, and had tons of CGI work in it. We had good contacts with the right people, and we did some amazing tests (I have videotape!) of the Enterprise that blew the modelmakers away. But they were too scared Omnibus would go under to give us the contract that would have saved us

In Canada, Pennie could point at the whirling logos of CTV and CBC on any television set to demonstrate how his company was on the leading edge of the industry.

But Pennie still wasn't satisfied. His ultimate goal was to own the computer graphics industry – all of it. This was the 80s – the Me decade, the decade of big bucks, and bigger bucks always just around the corner. In 1986, Pennie landed a really big sugar daddy, in the form of the Royal Bank. He had a megaplan, and now he was ready to go into action – south of the border.

The two largest computer graphics companies in the United States at that time were Digital Productions and Robert Abel & Associates Inc. In June, 1986, backed by various investors and $6 million of the bank's money, Omnibus swallowed Digital. In October, it dropped $7.3 million to take over Abel & Associates. Pennie could see his dream starting to unfold. Omnibus now controlled the North American computer graphics industry (and had a pair of $13 million Cray supercomputers to prove it). Unfortunately, the founders and management of these two companies didn't share Pennie's grandiose vision, and they got out fast.

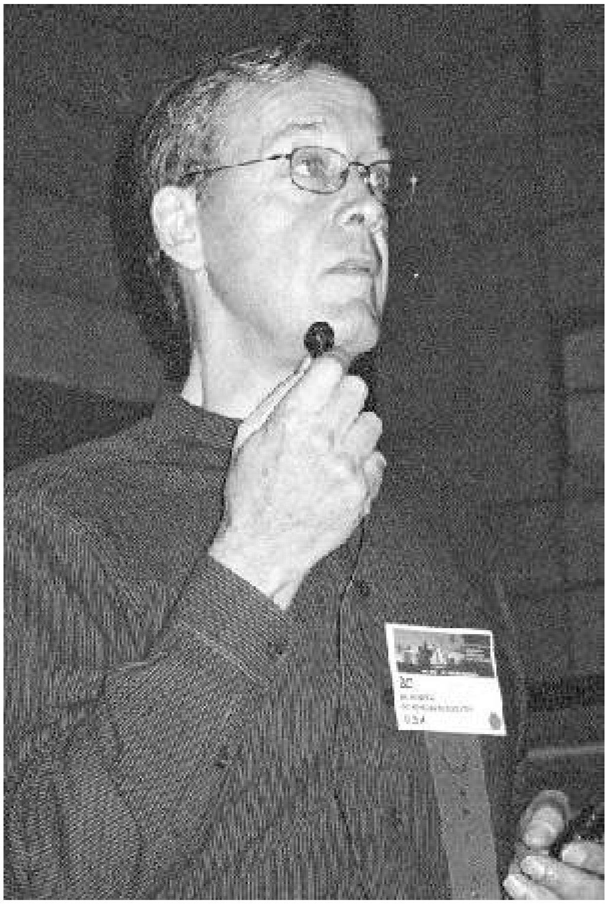
The dream didn't last long. By March, 1987, Omnibus was sinking under the weight of $30 million in debt and in default on its loan agreements; in May it was in bankruptcy, leaving the American computer graphics industry in ruins. Omnibus was omnibust, and the cream of the continent's digital animators were out on the street.

Such is the nature of influence. One individual's actions can alter the course of a whole industry. In the case of John Pennie, his overzealous attempt to dominate an industry wound up shattering it. Yet the demise of Omnibus spawned a host of smaller, more aggressive companies throughout the U.S. and Canada (one of which is Toronto's Side Effects Software) and the computer graphics industry successfully regenerated itself with new technologies and new visions to become what it is today.

**Movie 6.37** Omnibus demo

*1985 commercial demo reel for Omnibus Computer Graphics*
https://www.youtube.com/watch?v=K18ZcE2t1Kw

# 6.9 Bo Gehring and Associates



Bo Gehring was at Cornell University in Electrical Engineering when he became interested in design. He quit the EE department in 1961 and worked with welding metal sculptures and running a machine shop. When the computer industry expanded, his shop was hired to design and build computer-controlled drilling machines for IBM circuit boards. Gehring was hired by Phil Mittleman of MAGI in 1972 to develop the division of the company focused on computer image making (MAGI Synthavision). Gehring later moved to LA to create test sequences for Steven Spielberg's *Close Encounters of the Third Kind*. and started his own company, Gehring Aviation, in 1977. He later renamed the company as Bo Gehring and Associates, which focused not on the film industry but the advertising industry[1].

*Bo Gehring*

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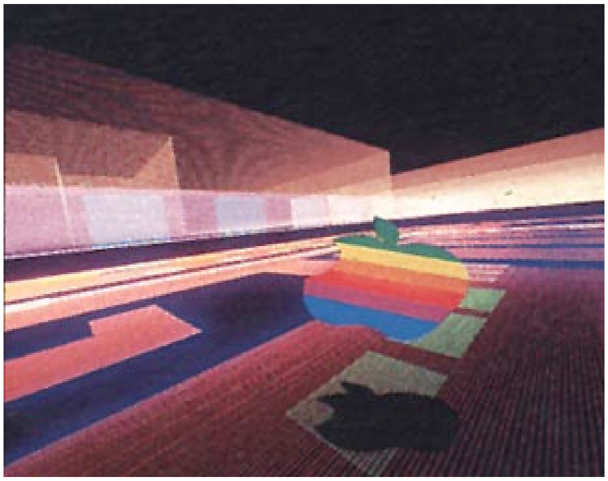
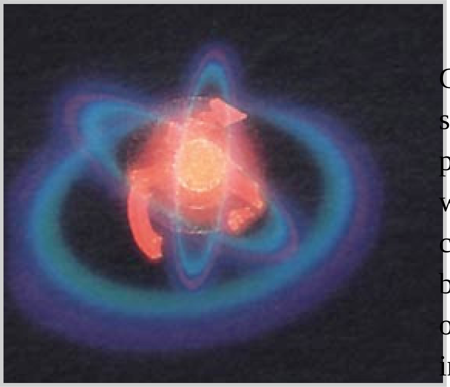
[1] There were many small, boutique type production companies contributing to the CGI industry in the late 1970s and early 1980s. Gehring is an example of the kind of company that was important to the evolution of the industry.

Gehring produced animation for the films *Demon Seed* (1977, with Julie Christie and Fritz Weaver) and *Nightmares* (1983, with Emilio Estevez and Moon Zappa). He also worked with the famous television promotion producer *Harry Marks*. Although the film industry beckoned those companies in LA, Gehring chose to stick with television. “Ninety million dollars is spent each day on advertising in the United States,” Gehring told *Greg Bear* in an interview. “Feature films can’t begin to match that level of financing. I’m secure where I am.”


*Apple Computer ad produced by Gehring*

Two years later, Gehring was producing about half of his work for feature films, and the other half for advertising at Venice-based Gehring and Associates. His “boutique” business had several motion control tracks and several high end vector and raster systems, but he often did the front end design for productions, and contracted with other companies (eg, Triple-I and Cranston/Csuri) for the image computation and compositing in order to keep his capital costs at a minimum. This focus on software investment at the “front-end” resulted in the development of one of the first film scene tracking software algorithms (STAR- Scene Tracking Auto Registration), a sort of electronic **rotoscoping** system (assistance in the coding was provided by Jim Clark, later of SGI fame).


Frame from ABC promotion


Frame from KCOP-TV promotion

Gehring also was interested in digital sound synthesis. “I’m one of those people who has to pull off the road when something really intriguing comes on the car radio. I firmly believe that sound is at least the equal of sight in bandwidth– complexity of information–and synthetic sound is a fascinating area that’s barely been explored.” (also from the Greg Bear interview) After the closing of his Venice based company, he moved to Canada for a stay at Banff, where he pursued his audio interest, starting a company called Focal Point to develop software for the Mac.

According to Gehring: “The Focal Point 3D Audio system takes any sound and processes it to generate signals for each ear. It’s a cursor for the sound,” he explained. “It’s the same sound as before, but built into it is new information to make the brain think it’s coming from a new direction”. He also has been involved with a design company, Third Rail Ops, and resides in Beacon, New York. According to their website, Third Rail Ops “provides design and production support to artists and architects. At the heart of the practice is a projection theater where works are visualized full size in three dimensions. The latest computer technology, in-house CNC machining, large format printing, and a seasoned network of services such as rapid prototyping and large-scale fabrication complete the picture.”

Gehring recently won the 2013 Outwin Boochever Portrait Competition. He conceived and executed a short video of Esperanza Spalding that was included in the national portrait gallery of the Smithsonian [2]

*Gehring ad from 1983 Computer Pictures trade magazine*

**Movie 6.38** Gehring demo reel

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[2] "A vein on the left side of Esperanza's neck pulses; the fabric of her dress accordions faintly out and in with each breath; her finger twitches and grains of mascara ride eyelids that halfway conceal two smiling eyes. Welcome to the intimacy of slow and the close-up video portraiture of Bo Gehring on view in the Smithsonian's National Portrait Gallery exhibition *Eye Pop: The Celebrity Gaze*." http://www.e-torch.org/2016/03/up-close-and-extremely-personal-the-video-portraiture-of-bo-gehring/ He has a video that shows the portrait creation process at http://www.bogehring.com/VIDEO/portraits/how_it_works_video.html

*1983 commercial demo reel from Bo Gehring & Associates https://www.youtube.com/watch?v=Es8VdR-E8Wg*

**Movie 6.39** Marks and Marks Demo (Harry Marks 1981)

*http://www.youtube.com/watch?v=6c3nWhR41D0*

# Chapter 7: Organizations, conferences, & graphics standards

# Organizations, conferences, & graphics standards

Several professional organizations grew with the emerging computer graphics industry. These organizations started some conferences, including the influential ACM-SIGGRAPH conference, and attempted to define important standards for the discipline.

# 7.1 CG Organizations and Conferences

The IEEE Computer Society is the world's leading organization of computer professionals. Founded in 1946, it is the largest of the 37 societies of the Institute of Electrical and Electronics Engineers (IEEE) with nearly 100,000 members.

*IEEE Logo*

In 1947, members of the computing community founded a professional organization called the Association for Computing Machinery (ACM), to provide professional and educational opportunities for its members. It has grown to approximately 75,000 members from every area of the computing related field.

*ACM Logo*

The American Federation of Information Processing Societies (AFIPS) was established on May 10, 1961, to advance and disseminate knowledge in the field of information science, and to represent member societies on an international level. The federation was an outgrowth of the National Joint Computer Committee, which was established in 1951 to sponsor the Joint Computer Conferences. The founding societies of AFIPS were the Association for Computing Machinery (ACM), the American Institute of Electrical Engineers, and the Institute of Radio Engineers (the latter two eventually merged into the IEEE, or Institute of Electrical and Electronic Engineers). One of the main contributions of AFIPS was its sponsorship of the Joint Computer Conference, renamed the National Computer Conference in October 1973. These semi-annual conferences featured technical sessions and exhibits relating to the field of information processing. They were discontinued after 1987 because of the financial condition of the organization

One of the unique components of the ACM organization is the Special Interest Group, or SIG (in the early days they were called Special Interest Committees, or SICs). The individual computing specialty areas are represented in one of these 35 SIGs. Like the umbrella ACM organization, each SIG is governed by a board made up of volunteer members.

In 1967, one of the ACM Board members was Sam Matsa, who started his career as part of the IBM/GM relationship that would result in DAC-1 and the IBM 2250 display. Matsa and Andy Van Dam of Brown University organized a professional development seminar in graphics as part of a larger series of seminars. Matsa convinced ACM to sponsor these seminars, which traveled around the country, attracting 40 or 50 people to each. In the graphics seminar, Van Dam taught the hardware side and Matsa taught the software component.

As a result of the interest in the graphics discipline, evidenced by the attendance at these seminars, Matsa and Van Dam convinced ACM that they should recognize a Special Interest Committee in Graphics, and SICGRAPH was born. Matsa was the founding Chairman and Van Dam as Secretary organized the SIC newsletters.

In 1969, the members wanted recognition of the area in the way other computing disciplines were recognized, with elected rather than appointed officers, so a lobbying effort resulted in enough signatures to convince ACM to give the SIC a Special Interest Group designation, and ACM-SIGGRAPH was established. Its first elected chair was Ed Devine. Jon Meads named it SIGGRAPH: the Special Interest Group on Computer Graphics and Interactive Techniques in the bylaws, in order to recognize the graphics and the human interaction parts of the equation.

*SIGGRAPH 84 Logo*

The organization participated in the broader ACM conferences, and published a quarterly newsletter. Interest ran the gamut from simulation and modeling, to text editing and composition, to computer generated art, cartography and mapping, computer aided design and, computer graphics software and hardware.

In 1973, Meads and Bob Schiffman organized the first annual SIGGRAPH conference, which has become one of the compelling aspects of the organization. It was held in Boulder, Colorado in the summer of 1974 as the 1st Annual Conference on Computer Graphics and Interactive Techniques. Attendance was approximately 600 people. There were no formal proceedings published, rather the papers were included in an obscure journal from Pergammon Press. The next two conferences, at Bowling Green, Ohio and Philadelphia, were only moderately successful. In 1977 the conference was held in a Hyatt in San Jose, and it was a resounding success, leading to decades of successful and important SIGGRAPH conferences. The Proceedings of the Conference remains an accepted scholarly journal for the publication of technical contributions.

SIGGRAPH Logo

Tom DeFanti, who graduated from Ohio State and later served as SIGGRAPH Chair, organized film and video presentations in the early conferences, and in 1979 started publishing them as the SIGGRAPH Video Review. These sessions are now called the Electronic Theatre, part of the Computer Animation Festival, a juried conference event. In 1995, Frank Foster arranged to have this evening of visuals in a formal theatre setting, away from the conference venue, at the famous Shrine Auditorium in LA.

Over the years, Panels and Courses were added, an Art Show became a mainstay, and venues for emerging technologies were provided. Several related conferences have occasionally co-located with SIGGRAPH, and an Education track became part of the overall conference offerings.

*The above section is based in part on an article in the SIGGRAPH newsletter by Carl Machover. http://www.siggraph.org/*

*NCGA Logo*

The National Computer Graphics Association (NCGA) was founded in 1979 by Joel Orr and Peter Preuss. It evolved from the standardization efforts of SIGGRAPH, and some frustration that the industry was not necessarily being served well by a single entity in the form of SIGGRAPH. It held its first conference in Virginia in 1980, with an expanded equipment exhibition, workshops and tutorials for attendees, and an award program for images and videos (SIGGRAPH chose not to pick any "best of…" until 2003.) For many years, it was important for graphics professionals to attend both conferences, but during the downturn in the 90s, NCGA fell on financial hard times, and is now defunct. Several subgroups of NCGA, such as the CAD Society have survived. It is an occasional informal gathering of professionals–vendors, consultants, and users–who are interested in CAD.

First UAIDE Conference

In 1980, the European Computer Graphics Organization, Eurographics was formed. They held their first conference in Geneva that year. There were also organizations in Australia (Ausgraph), Canada, the Netherlands (ISEA – The Inter-Society for the Electronic Arts ), Japan (Nicograph's first conference was held in 1982) and elsewhere. The CGS (Computer Graphics Society) was formally founded in Geneva in 1992. Also, beginning in 1962 the Users of Automatic Information Display Equipment (UAIDE) annual conference was the home for leading edge computer graphics papers until SIGGRAPH came along. During the mid-1980s, Pratt Institute in New York sponsored an annual conference (ComGraf), and there were conferences in Paris (Parigraph), London (ComputerFX), MonteCarlo (Festival International de Television de Monte Carlo), Canada (Graphics Interface), and many other locations in the U.S. and abroad. Besides SIGGRAPH and NCGA, a big conference for CAD professionals was the Design Automation Conference. *(See Machover's UAIDE discussion in the May 2000 SIGGRAPH newsletter).*

Eurographics was formally founded in spring 1980. Under the chairmanship of José Encarnação, it was given its first operational structure, composed of an Executive Committee, an Executive Board, a Workshops and Books Board, a Professional Board and a Conference Board.

Two years later, the British Chapter was founded. The Computer Graphics Forum started and first contracts were made with ACM-SIGGRAPH (USA), Austrian Computer Graphics Association (A), British Computer Society (UK), Gesellschaft fuer Informatik (D), the J. von Neumann Society (H) and the NCGA (USA). In 1984, now under the chairmanship of Paul ten Hagen, the German Chapter followed. Affiliation agreements between GI (D) and EG, and between SIGRAD (S) and EG were made in 1985.

In 1986 Carlo Vandoni took the lead, and in June, Eurographics was registered at the "Registre du Commerce" in Geneva. The Spanish Chapter was founded 1987, the Portuguese Chapter followed only a year later. Moreover, affiliation agreements with the Austrian Computer Graphics Association (ACGA), the German Computer Society

(GI), the Norwegian Computer Graphics Scociety (NORSIGD) and the Swedish Graphics Interest Group (SIGRAD) were made along with liaison agreements with societies in China and Japan.

The years 1987-1988 represented a period of stabilization for the Eurographics Association with respect to the number of individual and institutional members thanks to various promotional activities. Also, the services offered to members improved considerably: student and spouse membership were introduced, the CGF appeared at rather regular intervals and discounts to members for IEEE CG&A and for the Springer series were offered.

*Eurographics Logo*

More affiliation agreements were made with the French Computer Society (AFCET), the Italian Computer Society (AICA), the Finnish CAD/CAM Association, the Dutch Computer Society (NGI) and with the Swiss Computer Graphics Association (SCGA) and the Nicograph Association in 1989 and 1990 under the chairmanship of Roger Hubbold. Under his lead, the EG conference proceedings were made a special issue of CGH. Furthermore, the official EG logo was created at that time, programmed by hand in PostScript.

At this time, the working groups for Pictures and Multimedia, Computer graphics and AI, Computer graphics Hardware, Scientific Visualization, Relationships Between Image Synthesis and Image Analysis were established.

In 1991, Jürgen Schönhut was elected chairman of the EG Association. The Editor of Computer Graphics Forum changed to NCC Blackwell Publishers and H.P.Seidel was announced its new chief editor. In 1992, David B. Arnold took over as Chair. A new agreement with Springer Verlag to publish the Eurographics Workshops in the new “Focus on Computer Graphics” series was made in 1993. EG started its web presence in 1995 by establishing its website under the lead of Ivan Herman.

In May 1996, on a workshop on the future of Eurographics, the main focus of EG was set as “an association of professionals to help professionals in their careers in computer graphics and interactive digital media”. Under the presidency of W.T.Hewitt, a liaison agreement with the Chinese Computer Graphics association was also signed that year. In the following year, the Eurographics publications catalogue got inaugurated on the website www.eg.org, replacing the printed catalogue.

In 1999, under the lead of Dieter Fellner, the Online Board was instated and the cooperation agreement between Eurographics and SIGGRAPH was renewed. In 2000, due to this cooperation, EG for the first time was operating a stand outside the exhibition area and next to the SIGGRAPH, being a vital sign of EG and showing its standing in the graphics world. In the same year, a cooperation with IEEE TCVG was signed and the digitization of back issues of Computer Graphics Forum started.

The Italian Chapter was founded in 2001 under the presidency of P.Brunet. In 2003 the French Chapter started.

(From History page of the EG website *https://www.eg.org/index.php/about-eg/history*)

# 7.2 Graphics Standards

In 1916 the American Institute of Electrical Engineers (now IEEE) invited the American Society of Mechanical Engineers (ASME), American Society of Civil Engineers (ASCE), American Institute of Mining and Metallurgical Engineers (AIMME) and the American Society for Testing Materials (ASTM) to join in establishing a national body to coordinate standards development and to serve as a clearinghouse for the work of standards developing agencies.

Two years later, the American National Standards Institute, or ANSI, originally founded as the American Engineering Standards Committee (AESC) was formed to serve as the national coordinator in the standards development process as well as an impartial organization to approve national consensus standards and halt user confusion on acceptability. The five organizations invited the U.S. Departments of War, Navy and Commerce to join them as founders.?(See *http://www.ansi.org*)

The International Organization for Standardization (ISO) was established in 1947 to define "specifications and criteria to be applied consistently in the classification of materials, in the manufacture and supply of products, in testing and analysis, in terminology and in the provision of services." In the field of CG, this can mean applications portability, graphics package portability, host machine independence, device independence, programming language independence, interoperability, and perhaps even programmer and operator portability.

The standardization process in CG started in the mid-60s. A number of software packages helped define "de-facto" standards for the portability of graphics programs. For example, Plot-10 from Tektronix, Cambridge University's GINO-F and Culham Lab's Ghost all provided for certain standardization, but there were problems with each of them. Also, there were european efforts for standardization that were progressing, most notably the German Standards Institute, or DIN, and the Norwegian group which proposed a package called GPGS as a standard. GPGS later became known as IDIGS.

The International Federation of Information Processing, or IFIP, is a non-governmental, non-profit umbrella organization established in 1960 for national societies working in the field of information processing. It established Technical Committees, or TCs (Foundations, Software Theory and Practice, Education, Applications, etc), each of which established Working Groups, or WGs, responsible for different activities within the context of the TC.IFIP WG 5.2, Computer Aided Design , belongs to IFIP TC 5, Computer Applications in Technology. It was established in 1972, and revised in 1986.

In 1972, ACM established an informal Graphics Standards Planning Committee, or GSPC. They met periodically, and discussed ideas that could possibly result in some kind of standardization. They organized and held a Workshop on Machine Independent Graphics at the National Bureau of Standards in 1974, and formalized themselves as the GSPC, but their activities soon (in the words of Robin Williams) languished for a few years.

In May of 1976, a Workshop on Graphics Standards Methodology was organized by Richard Guedj under the auspices of IFIP WG 5.2 in Seillac, France. Called Seillac I, the workshop was attended by representatives from all over the world who all agreed that it was extremely important to develop a sound methodology, and perhaps a new language conforming to that methodology. The Seillac workshop decided 1) to begin the standardization efforts with the application program interface, or API, 2) to separate the modeling of a scene from the viewing of a scene, and 3) to assure language independence.

*SIGGRAPH 77 Proceedings cover*During the SIGGRAPH 76 conference, GSPC was reactivated. Bob Dunn and Bert Herzog became the leaders of a group of 25 expert volunteers, divided into groups to deal with short-term issues and longer-term core issues that were identified both from their previous work as well as the Seillac workshop. In particular, they decided that a “State of the Art” group would survey existing software packages and approaches; a “Methodology group would look at a conceptual framework and guidelines; a “Core” group to define the semantics of a standard graphics package; and an “Interface” group that would consider interoperability with other software technologies. The Core recommendations were published in a supplement to the Proceedings of the SIGGRAPH 77 Conference.

*SIGGRAPH 77 Proceedings cover*

ISO also established a working group, ISO WG2, the Graphics Working Group, to study the issues. They met in Bologna in 1978 and considered reports from DIN, the GSPC Core group, and IDIGS. The DIN report was called GKS, or Graphical Kernal System, which unlike Core, only dealt with 2D. They met again in Amsterdam in early 1979, and recommended that GKS and Core come closer together. DIN and GSPC met in Boulder, Colorado to discuss these recommendations.

In June, 1979 the Core work was passed to ANSI, which organized a working group called X3H3 to develop a standard based on Core. X3H3 ultimately recommended a standard called PHIGS. In the meantime, an ISO workshop was held in Budapest in October, 1979 to consider GKS version 5.0, as well as Core and a version of IDIGS. It decided to focus on GKS only. Following discussions at the Eurographics Geneva conference, the proposal for GKS as a two-dimensional standard for Computer Graphics was submitted to ISO. Some think that if the SIGGRAPH Core proposals had been submitted to ISO in the previous year then it is probable that ISO would have considered a two-dimensional standard unnecessary, but the GSPC had neglected to do this. The submission of the GKS proposal to ISO was followed by lengthy discussions with all interested parties and some of the ideas of the Core, especially those relating to forms of text output, were incorporated into GKS before it was published in 1982 as Draft International Standard 7942.

Discussions continued on minor details of 7942, and it has been said that the GSPC were not happy with the emergence of GKS. SIGGRAPH organized a vote of its members to decide whether it or ISO should be the appropriate authority to decide on standards for Graphics in America and the vote fell solidly in favor of ISO. In February 1984, SIGGRAPH published a special issue describing GKS which was sent to all its members, and it became the first published standard for graphics in August, 1985.

GKS defines a basic two-dimensional graphics system with uniform input and output primitives and a uniform interface to and from a GKS metafile for storing and transferring graphics information. It supports a wide range of graphics output devices including such devices as printers, plotters, vector graphics devices, storage tubes, refresh displays, raster displays, and microfilm recorders. As the technical work on GKS came to a close, attention was turned to issues of 3D. Some wanted to extend GKS, while others, most notably the U.S. introduced a new system, called PHIGS. It was agreed at a joint meeting in Canada in 1983 to launch both projects.

PHIGS stands for Programmer’s Hierarchical Interactive Graphics System. The PHIGS standard defined a set of functions and data structures to be used by a programmer to manipulate and display 3-D graphical objects. The standard was approved by ANSI as ANSI X3.144-1988, by ISO as ISO 9592-1:1989, and by the Federal government as Federal Information Processing Standard (FIPS) 153.

GKS-3D is a pure super-set of GKS designed to handle 3D graphics in a compatible way. That is to say, a 2D application written to the GKS standard is guaranteed to run in a GKS-3D environment without change. However, apart from the usual GKS functions, GKS-3D provides additional ones to handle 3D primitives, 3D input, and 3D viewing. It was standardized as ISO 8806-1 in 1988.

Discussions on the limitations of PHIGS in the area of rendering (output primitives) resulted in the recommendation and adoption of PHIGS+ in 1989.

Work on a Metafile standard for the storage and transfer of picture description information was approved in 1983, and ISO approved the Computer Graphics Metafile (CGM) standard in 1987 as ISO 8632. This standard defines the format of a file that describes one or more two-dimensional images. A CGM metafile is not a picture – it only contains a description of the picture. In order to see the picture, the information in the file must be translated by another program for a specific output device. Pictures are described as a collection of elements of different kinds, representing things like primitives, attributes, and control information.

CAD (Computer-Aided Design) systems had been developing their systems well before the standards activities took place. They were concerned with a metafile for transferring these files between CAD systems. Products may be designed as either a two-dimensional, three-view drawing layout, or as a full three-dimensional model with associated drawing views and dimensions using a CAD system. The Initial Graphics Exchange Specifications, or IGES format serves as a neutral data format to transfer the design to a dissimilar system. Translators, developed to the IGES Standard, are used to export a design into an IGES file for exchange and for importing the IGES file into the destination system.

“In 1979 events took place that catalyzed the CAD vendor community to create the first national standard for CAD data exchange. Mechanical CAD systems were less than ten years old, and there were only a handful of products with any significant market penetration. Even at this early stage, users were overwhelmed by the inability to share data among these tools and with their own internally-developed databases. Frustration was evident at a fateful two-day Society of Manufacturing Engineers (SME) meeting in the Fall of 1979. On the first day, an attendee from General Electric (GE) challenged a panel of CAD vendors, that included Computervision, Applicon, and Gerber, to work together to enable a common neutral exchange mechanism.

The panel reported on the second day, and the wheels were set in motion to create an ‘IGES.’ Once the panel admitted that a common translation mechanism was possible, it was impossible to stop the momentum of the customer’s enthusiasm and expectations. Applicon and ComputerVision agreed to open their internal databases, GE offered its neutral database, and Boeing offered the structure of its Computer Integrated Information Network (CIIN) database. Both GE and Boeing contributed their existing translators. A core team was formed that included representatives from NBS, Boeing, and GE. Team members had worked closely with each of the vendors on internal integration projects. This prior experience built the expertise and trust needed to craft a solution in a very short time, and neither vendor felt it gave an unfair advantage to the other.


IGES Logo

Soon after, an open meeting was held at the National Academy of Sciences on October 10, 1979. Approximately 200 people attended to herald the birth of IGES.” ?*Quoted from B. Goldstein, S. Kemmerer, C. Parks, “, A Brief History of Early Product Data Exchange Standards” NISTIR 6221, September 1998.*

See *http://www.nist.gov/iges/*

The mid-1980s saw the use of CAD playing a more significant role in aircraft design. Boeing decided to design its 777 aircraft totally on the computer, using CATIA. In Europe, a consortium of manufacturers (Aerospatiale(France), British Aerospace, CASA (Spain) and MBB (West Germany)) began the design of the Airbus 320 totally using CAD. The differing systems used by these companies demanded a standard for data interchange, and the SET (Standard D’Exchange et De Transfert) standard was developed. It was seen by many to be the main challenge to the IGES standard evolving in the U.S. SET began development in 1983 at Aerospatiale as a response to the halting implementation of the IGES standard, and because it was developed in one company, its proponents argued that it was faster and more dependable. Others, including U.S. standards officials, saw the emergence of two competitive standards as an impediment to the acceptance of a standard, because of problems of interpretation and agreement among standards makers.

Other standards which have been adopted (some are not official standards, but rather can be considered industry standards) include OpenGL (1992) from SGI, Java-2D and Java-3D from Sun, DirectX (1995) from Microsoft, X-windows (developed at MIT in the late 1980s ), PEX (PHIGS extension to X), PostScript, VRML, NTSC (PAL and SECAM), D1 (D2, D3, D5) and many more.

Although it is beyond the scope of this Section to accurately define file formats for graphics, it is worth noting that several have become de facto standards, and several more have come out of actual standards working groups and have either been designated as standards, or are being considered. For example, JPEG is an adopted standard (ISO WG 10, 1991) for encoding and compressing continuous tone raster still images. It was proposed by the Joint Photographics Expert Group, hence its name. Likewise, MPEG (ISO WG11, 1991) is a standard for encoding video and audio sequences, from the Moving Picture Experts Group. Below is a list of some other more popular formats:[1]

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[1] The National Archives has a detailed description at https://www.nationalarchives.gov.uk/documents/graphic-file-formats.pdf

| **Format** | **Developer** | **Purpose** |
|---|---|---|
| BMP (BitMaP) | Microsoft | raster; color independence |
| CCITT | Fax CCITT | document transmission |
| DXF (Drawing eXchange File) | Autodesk, Inc. | interchange AutoCAD files |
| EPS (Encapsulated PostScript) | Adobe | describes a single picture that can be included in a PostScript file |
| GIF (Graphics Interchange Format) | Compuserve | uses LZW compression for transmission over telephone lines; has become a Web standard |
| JFIF | C-Cube Microsystems | Portable JPEG |
| PICT (PICTure data) | Apple | optimized for Apple QuickDraw |
| QuickTime | Apple | storage and retrieval of compressed time-based data |
| RLE (Run Length Encoding) | University of Utah | device independent raster |
| TIFF (Tag Image File Format) | Aldus | raster scanned data format |
| | | |

# 7.3 Early Graphics Publications

Over the years since the graphics discipline began there have been a number of graphics journals and publications, most of which are still being published [1]. They include:

**U.S. Journals**

- ACM Transactions on Graphics (TOG)
- Communications of the ACM (CACM)
- Computer Graphics (Proceedings of the SIGGRAPH Conference)
- Journal of the ACM (JACM)
- ACM Computing Surveys (defunct)
- IEEE Computer Graphics and Applications (CG&A)
- IEEE Transactions on Visualization and Computer Graphics
- IEEE Spectrum
- Graphical Models and Image Processing
- Computer Graphics and Image Processing
- Computer Graphics, Vision, and Image Processing (formerly CGIP)
- International Journal of Computational Geometry and Applications
- journal of graphics tools
- Computer Graphics World (CGW)
- Graphical Models (formerly Graphical Models and Image Processing)

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[1] Professor Bill Hill from Jacksonville University, has a recommended list of books and magazines (annotated) on his course website at *http://users.ju.edu/whill/bca/resources.html* that includes some of the above resources and expands it with references to books on computer animation.

- High Performance Computer Graphics, Multimedia and Visualization
- IEEE Transactions on Visualization and Computer Graphics (TVCG)
- Proceedings of the National Computer Conference (defunct)
- Proceedings of the Fall Joint Computer Conference (defunct)
- Proceedings of the Spring Joint Computer Conference (defunct)
- AFIPS (American Federation of Information Processing Societies)
- IBM Systems Journal
- UAIDE (Users of Automatic Inform. Display Equipment) (defunct)

**European Journals**

- The Visual Computer
- Computer-Aided Design
- Computer Aided Geometric Design
- International Journal of Shape Modeling
- Computers & Graphics
- Computer Graphics Forum, editors
- The Journal of Visualization and Computer Animation
- Computational Geometry
- Machine Graphics and Vision
- IFIPS (International Federation of Information Processing Societies)

Also, popular publications like Scientific American, Byte Magazine, Computer Pictures, Datamation and others have published graphics articles. Esoteric journals in related areas (Journal of Approximation, Applied Mathematics, SAE, …) and proceedings of small conferences were publishing venues for graphics researchers. Several publishers produced newsletters for the industry, including the S. Klein Newsletter, the Roncerelli Report and Pixel News, Joel Orr's Computer Graphics Newsletter (which evolved into Computer Graphics World Magazine), the SIGGRAPH newsletter, and others.

**Computer Graphics related books**

- R. Bartels, J. Beatty, & B. Barsky, An Introduction to Splines for Use in Computer Graphics and Geometric Modeling, Morgan Kaufmann Pub., 1987.
- M. de Berg, M. van Kreveld, M. Overmars, & O. Schwarzkopf, Computational Geometry – Algorithms and Applications, Springer Verlag, 1997.
- Wolfgang Boehm & Hartmut Prautzsch, Geometric Concepts for Geometric Design, A. K. Peters Pub., 1993.
- J.-D. Boissonnat & M. Yvinec, Algorithmic Geometry, Cambridge University Press, 1998.

- Michael Cohen & John Wallace, Radiosity and Realistic Image Synthesis, Academic Press, 1993.
- Gerald Farin, Curves and Surfaces for Computer Aided Geometric Design, 4th edition, Academic Press, 1996.
- Gerald Farin, NURB Curves and Surfaces, A. K. Peters Pub., 1995.
- E. Fiume, Mathematical Foundations for Computer Graphics, Academic Press, 1989.
- J. Foley, A. van Dam, S. Feiner, & J. Hughes, Computer Graphics: Principles and Practice, 2nd edition, Addison-Wesley, 1996.
- Andrew Glassner (Ed.), Graphics Gems, Academic Press, 1990.
- S. Harrington, Computer Graphics, A Programming Approach, McGraw-Hill, 1987.
- Andreas Hartwig, Algebraic 3-D Modeling, A. K. Peters Pub., 1996.
- D. Hearn & M. Baker, Computer Graphics, Prentice-Hall, 1986.
- F. Hill, Computer Graphics Using Open GL, 2nd edition, Prentice-Hall, 2000.
- C. Hoffmann, Geometric and Solid Modeling: An Introduction, Morgan Kaufmann Pub., 1989.
- S. Hoggar, Mathematics for Computer Graphics, Cambridge University Press, 1992.
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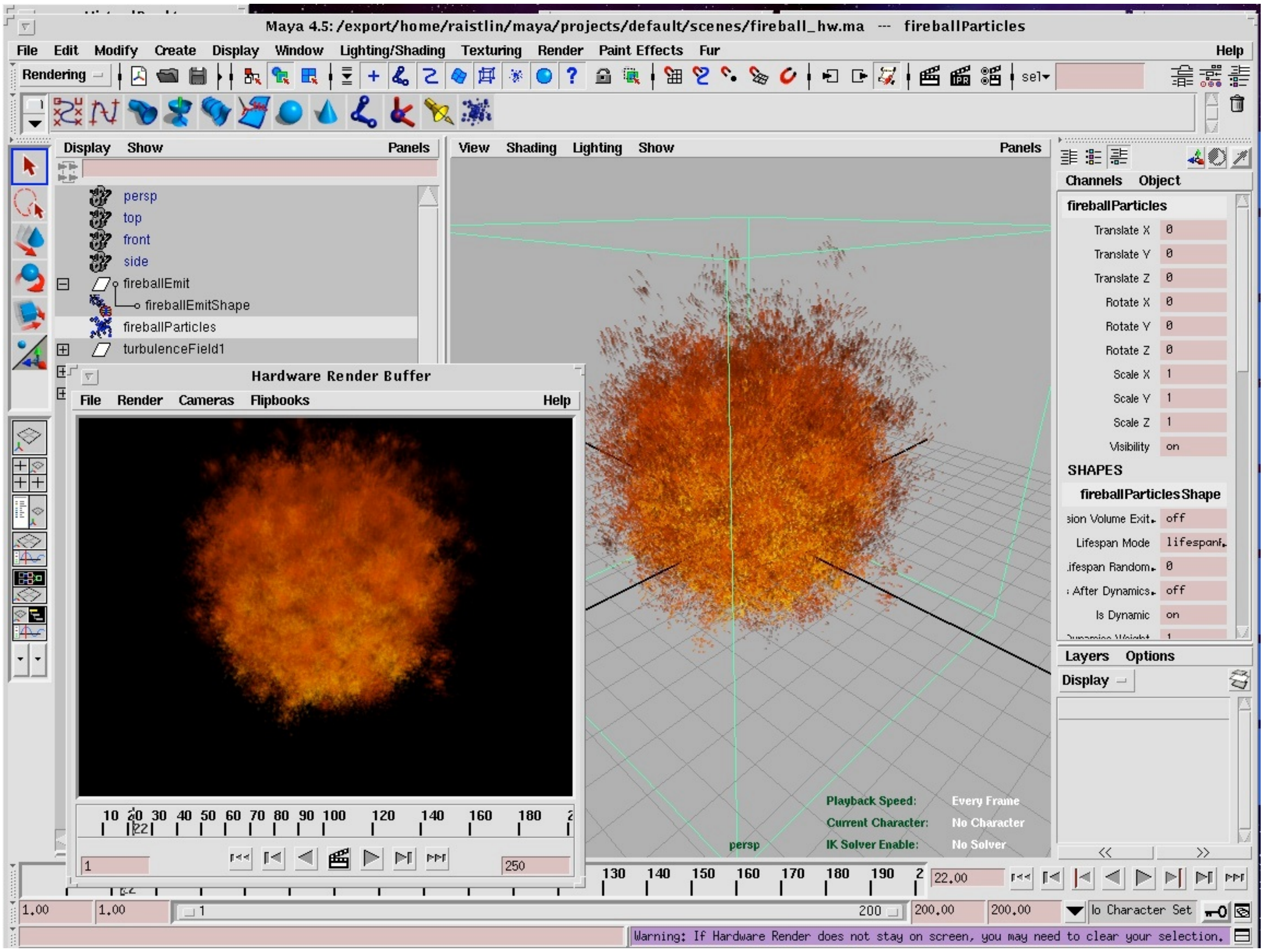
- Charles Micchelli, Mathematical Aspects of Geometric Modelling, SIAM Pub., 1995.
- Michael Mortenson, Geometric Modeling, John Wiley, 1985.
- William Newman & Robert Sproull, Principles of Interactive Computer Graphics, 2nd edition, McGraw-Hill, 1979 (1st Edition – 1973).
- Joseph O'Rourke, Computational Geometry in C, 2nd edition, Cambridge University Press, 1998.
- Clifford Pickover, Computers, Pattern, Chaos, and Beauty, St. Martin's Press, 1990.
- F. Preparata & M. Shamos, Computational Geometry – An Introduction, Springer-Verlag, 1988.
- D. Rogers & J. Adams, Mathematical Elements for Computer Graphics, McGraw-Hill, 1976.
- F. Sillion & Claude Puech, Radiosity & Global Illumination, Morgan-Kaufmann Pub., 1994.
- Eric Stollnitz, Tony DeRose, & David Salesin, Wavelets for Computer Graphics, Morgan-Kaufmann Pub., 1996.
- A. Watt, 3-Dimensional Computer Graphics, Addison-Wesley, 1990.
- A. Glassner, Principles of Digital Image Synthesis, vol. 1&2, Morgan Kaufman, 1995
- J. Blinn, Jim Blinn's Corner: A Trip Down the Graphics Pipeline, Morgan Kaufman, 1996
- J. Blinn, Jim Blinn's Corner: Dirty Pixels, Morgan Kaufman, 1998

- R. Fosner, OpenGL Programming for Windows95 and NT, Addison Wesley, 1998
- D. S. Ebert et al, Texturing and Modeling, 2nd edition, Academic Press1998.?Computer Vision and Image Processing
- D. Forsyth and J. Ponce, Computer Vision: A Modern Approach, Prentice Hall Inc., 2003
- V. Nalwa, A Guided Tour of Computer Vision, Addison Wesley, 1993
- E. R. Davies, Machine Vision: Theory, Algorithms, Practicalities, Academic Press, 1997
- S. E. Umbaugh, Computer Vision and Image Processing: A Practical Approach using CVIPtools, Prentice Hall, 1998
- R. Jain et al, Machine Vision, McGraw-Hill, 1997
- R. Haralick and L. Shapiro, Computer and Robot Vision, Addison Wesley, 1992
- B. K. P. Horn, Robot Vision, MIT Press, 1985
- D. Ballard and C. Brown, Computer Vision, Prentice Hall, 1982
- G. Wolberg, Digital Image Warping, IEEE Computer Society Press, 1990
- High Resolution Computer Graphics using Pascal/C, by Ian O. Angell and Gareth Griffith (John Wiley & Sons, 1988).
- Computer Graphics (C Version), by Donald Hearn and M. Pauline Baker (Prentice Hall, 1997).
- Advanced Animation and Rendering Techniques, Theory and Practice, by Alan Watt and Mark Watt (ACM Press/Addison-Wesley, 1992).

# Chapter 8: Commercial Animation Software

# Commercial Animation Software

CG researchers and programmers saw the value in taking the software that was being developed in the lab and making it more widely usable, either by selling or licensing it to animation companies.



Maya 4.5: /export/home/raistlin/maya/projects/default/scenes/fireball_hw.ma --- fireballParticles

fireballParticles

Translate X 0

Translate Y 0

Translate Z 0

Rotate X 0

Rotate Y 0

Rotate Z 0

Scale X 1

Scale Y 1

Scale Z 1

Visibility on

SHAPES

fireballParticlesShape

sion Volume Exit off

Lifespan Mode lifespanR

ifespan Random 0

After Dynamics off

Is Dynamic on

Playback Speed: Every Frame

Current Character: No Character

IK Solver Enable: No Solver

Warning: If Hardware Render does not stay on screen, you may need to clear your selection.

*Scene from Maya Software*

# 8.1 Introduction

*The following text was excerpted from an article by David Sturman, from the ACM SIGGRAPH Retrospective series published in the SIGGRAPH newsletter, Vol.32 No.1 February 1998. The entire article can be read at https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/09/sturman-animation.pdf*

Perhaps one of the earliest pioneers of computer animation was Lee Harrison III. In the early 1960s, he experimented with animating figures using analog circuits and a cathode ray tube. Ahead of his time, he rigged up a body suit with potentiometers and created the first working motion capture rig, animating 3D figures in real-time on his CRT screen. He made several short films with this system, called ANIMAC. This evolved into SCANIMATE which he commercialized to great success in 1969. SCANIMATE allowed interactive control (scaling, rotation, translation), recording and playback of video overlay elements to generate 2D animations and flying logos for television. Most of the 2D flying logos and graphics elements for television advertising in the 1970s were produced using SCANIMATE systems. In 1972 Harrison won an Emmy award for his technical achievements [25]. As computer graphics systems became more powerful in the 1980s, Harrison's analog systems began to be superseded by digital CG rendered keyframe animation, and now are no longer used in production.

The next widespread system was the GRAphics Symbiosis System (GRASS) developed by Tom DeFanti [at Ohio State University] for his 1974 Ph.D. thesis. GRASS was a language for specifying 2D object animation and although not interactive, it was the first freely available system that could be mastered by the non-technical user. With GRASS, people could script scaling, translation, rotation and color changes of 2D objects over time. It quickly became a great hit with the artistic community who were experimenting with the new medium of CG. In 1978 it was updated to work in 3D with solid areas and volumes and ran on a Bally home computer. This version was called ZGRASS, and also was important in bringing computer graphics and animation to the artistic community on affordable computing platforms [6].

Also in 1974, Nestor Burtnyk and Marcelli Wein at the National Film Board of Canada developed an experimental computer animation system that allowed artists to animate 2D line drawings entered from a data tablet. Animation was performed by point-by-point interpolation of corresponding lines in a series of key frames. The system was used for 1974 classic short film Hunger whose graceful melding of lines from one figure to the next won it an Academy Award nomination.

The New York Institute of Technology Computer Graphics Lab (NYIT), then under the direction of Ed Catmull, extended this idea, producing a commercial animation system called TWEEN. As with the National Film Board system, TWEEN was a 2D system that allowed the animator to draw key frames, and the computer interpolated corresponding line segments between the keys. TWEEN automated the process of producing in-between frames (sometimes called **tweening**), but still required the talents of a trained artist/animator for the keyframes. Although this method sped up the hand-animation process, animations produced this way had an overly distinctive fluid look and the method was not widely adopted for commercial animation.

The first complete 3D animation systems were typically in-house tools developed for use in particular academic environments or production companies. They could be categorized into two types of systems, scripted or programmed systems, and interactive keyframe systems. The first type were exemplified by ANIMA-II (Ohio State) [11], ASAS [23], and MIRA [16]. All three used a programming language to describe a time sequence of events and functions. When evaluated over time and a "snapshot" rendered at each animation frame, they produced the desired animation. ASAS is noteworthy since many of the CG sequences in the 1982 film TRON were animated with it. These systems were powerful in that almost anything could be done if it could be programmed, but limited in that programming skills were required to master them.

The keyframe systems were more amenable to animation artists. Based on the keyframe approach of traditional animation, these systems allowed the user to interactively position objects and figures in the scene, save these positions as keyframes and let the computer calculate the in-between frames to produce the final animation. GRAMPS [19] and BBOP [28] were examples of this type of system. Both relied on the real-time interactivity of the, then state-of-the-art, Evans & Sutherland Multi-Picture System, an excellent vector-graphics display system that worked from a display list allowing instantaneous updates of the on-screen graphics.

GRAMPS was developed for visualization of chemical structures although O'Donnell does give examples of how it could be used to animate a human figure. Ostensibly an interpreted script system, GRAMPS allowed script variables to be connected to dials for interactive manipulations.

An interesting aside: 2D and 3D animation.

BBOP was developed at the New York Institute of Technology's Computer Graphics Lab (NYIT) by Garland Stern expressly for character animation and was used extensively by NYIT in six years of commercial production. In BBOP, animators could interactively control joint transformations in a 3D hierarchy, saving poses in keyframes which the computer could interpolate to produce smooth animation. The system was very responsive and easy to use, and conventionally trained animators produced some remarkably good animation with it. Examples include a CG football player for Monday Night Football promotions, Rebecca Allen's CG dancer for Twyla Tharp's dance The Catherine Wheel, Susan Van Bearle's short film Dancers and numerous SIGGRAPH film show shorts featuring the digital characters User Friendly, Dot Matrix and User Abuser. These last three were some of the first CG characters to have expressive personalities that engaged the audience and brought CG to life. Much of this was due to an interactive keyframe system that gave the animator the control and freedom to manipulate the figures visually, in keeping with his training and experience.

Most modern commercial keyframe systems are based on the simple BBOP interactive keyframe approach to animation with added features that ease the animation process. At their core, they all have features of BBOP (some copied, some developed independently), including hierarchical skeleton structures, real-time interactive update of transformation values, interpolation of keyframes in channels so that different joints can have different keys in different frames, choice of **interpolation** functions such as linear, cubic, ease-in and ease-out, immediate playback and an interpolation editor.

In general, however, scripted systems still are best for repeated or easily describable movements, but require programming skills beyond the capabilities of most artists, especially as movements become more complex. Scripting expressive characters, for example, is extremely difficult, not to mention unnatural for an artist. Interactive keyframe systems are just the opposite. They allow artists to interact directly with the objects and figures within a familiar conceptual framework. But they become inefficient or tedious to use for mechanical or complex algorithmic motion. Because they are more easily used by artists, the interactive keyframe approach has won in the commercial software market. Curiously enough, as animators are becoming more sophisticated in their use of computer animation, scripting capabilities are beginning to reappear in keyframe systems. The newest version of Wavefront|Alias' MAYA animation system has a built-in scripting capability that allows animators to tie actions to events, define movement as functions of other movements, create macros and more.

Early 3D animation systems mostly dealt with simple forward **kinematics** of jointed bodies, however inverse kinematics can also be an important element in an animation toolkit. By moving just a hand or a foot, the animator can position an entire limb. Michael Girard [at Ohio State University] built a sophisticated inverse kinematic animation system for his Ph.D. thesis [9] which was used for producing very graceful human body movement in his 1989 film Eurhythmy. He later commercialized his system as a 3D Studio MAX plug-in, Biped (part of the Character Studio package), where legged locomotion such as walks, runs, jumps and skips can be animated by placing footprints. His inverse kinematic algorithms compute the motions of the figure that cause it to follow the footprints.

When Softimage was first released, it was the first commercial system to feature an inverse kinematics capability (although in a simplified form). That feature helped greatly in selling the new system. Now, almost all 3D animation systems have some form of inverse kinematic capabilities.

**Dynamics** is also an important tool for realistic animation. Jane Wilhelms was one of the first to demonstrate the use of dynamics to control an animated character [31]. Since then, James K. Hahn (Ohio State), David Baraff and Michael McKenna [12, 2, 17] have all described robust dynamics for computer animation. Yet it is only in the past few years that the major commercial systems are incorporating dynamics into their software. The problems they are facing are how to integrate dynamic controls, inverse kinematic controls, and forward kinematic controls within the same system, and presenting and resolving clearly the potentially conflicting constraints each puts on the animated elements.

Kinematics and dynamics deal with jointed skeletal structures. However, not all animation is skeletal. A face, for example, is a single surface with complex deformations. Fred Parke was the first to attack this problem [20] with a parametric facial model. Using parameters to describe key aspects of facial form, such as mouth shape, eye shape and cheek height, and then animating these parameters, he was able to simulate the motions of a human face as a single surface. The system was used by NYIT in a music video for the group Kraftwerk, but never commercialized.

Years later, **Philippe Bergeron** and Pierre Lachapelle digitized plaster models of several dozen expressions of a face, and created a system to interpolate between several of these target expressions at once for their 1985 short film *Tony de Peltrie* [3]. The result was a rubbery-faced character with a wide range of human expression. Rudimentary implementations of this technique of 3D object interpolation (or 3D target morphing) were incorporated into Softimage and Alias|Wavefront systems a few years ago, and are being improved for the latest versions of their software. 3D target morphing is also the basis of Medialab's real-time character performance animation system.

Keith Waters developed an even more sophisticated facial animation system based on muscle activation influencing regions of the face model [30]. This system produces very realistic facial motion and can be controlled by high-level commands to the muscle groups. His methods have not been commercialized, but simpler versions are used in some optical facial motion capture systems.

There follow a whole host of bits and pieces to animate particular effects. Some of these have been integrated into commercial animation systems. Others are used exclusively by the companies that developed them, while still others have just seen proof of concept and await a plug-in or incorporation into a more complete system.

The most influential of these (and perhaps not really in the bits and pieces category) is Bill Reeve's particle systems [22]. Reeves developed a method of using controlled random streams of particles to simulate fire, grass, sparks, fluids and a whole host of other natural phenomena. First used in the movie Star Trek II, particle systems are easy to implement and quickly appeared in many amateur, academic and professional CG animations, most notably Particle Dreams in 1988 by Karl Sims. Commercial animation systems took a little longer to incorporate the technique into their established structures, but today everyone has it in some form or another.

Other animation techniques for specific effects in the literature include (but by no means are limited to) automated gaits (walking, running, jumping, etc.) [5, 13], flocking behaviors [24, 1], fluid flow [14], waves [7, 21], smoke [27], sand [15], flexible objects [29], snakes [18], cloth [29] and many more.

As was already mentioned, the most difficult animation is character animation, particularly human character animation. In a quest for more realistic motion, people have looked towards directly recording the motions of a human performer. Lee Harrison III in the 1960s was only the first of many to use this concept. In 1983 Ginsberg and Maxwell [8] presented an animation system using a series of flashing LEDs attached to a performer. A set of cameras triangulated the LEDs' positions, returning a set of 3D points in real time. The system was used soon after to animate a CG television host in Japan. However motion capture systems and graphics computers were just not fast enough then for the real-time demands of performance animation.

When they did begin to become fast enough, around 1988 with the introduction of the Silicon Graphics 4D workstations, deGraf/Wahrman and Pacific Data Images both developed mechanical controllers (also known as waldos) to drive CG animated characters — deGraff/Wahrman for CG facial animation for a special SIGGRAPH presentation and for the film Robocop II, and PDI for a CG character for a Jim Henson television series and several other projects. For various reasons the technology and market were not ready and the systems were rarely exploited after their initial use.

Then, in the early 90s, SimGraphics, Medialab (Paris) and Brad deGraf (with Colossal Pictures and later Protozoa) all independently developed systems that allowed live performers to control the actions of a CG character in real time. These systems allowed characters to be animated live, as well as for later rendering. The results, particularly with Medialab's system, are characters that have very lifelike and believable movements. Animation can be generated quickly by actors and puppeteers under the control of a director who has immediate feedback from the real-time version of the character. All three systems have survived their initial versions and applications, and continue to be successfully used in commercial projects.

At first, these systems existed on their own and were not integrated into other commercial CG systems. Animation done in a keyframe system could not easily be mixed with animation performed in a real-time system. As time has passed, both the real-time systems and the keyframe systems have evolved, and now many keyframe systems have provisions for real-time input and the real-time systems import and export keyframe animation curves.

Performance animation has become very popular recently and at the SIGGRAPH 97 trade show, no less than seven companies demonstrated performance animation systems.

Similar to performance animation, but without the real-time feedback, are motion capture systems. These are generally optical systems that use reflective markers on the human performer. During the performance, multiple cameras calculate the 3D positions of each marker, tracking it through space and time. An off-line process matches these markers to positions on a CG skeleton, duplicating the performed motion. Although there are problems with losing markers due to temporary occlusions and the animation matching process can be very labor-intensive, motion capture permits an accurate rendering of human body motion, particularly when trying to simulate the motion of a particular performer as Digital Domain did with Michael Jackson's 1997 music video, Ghosts.

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For the entire dissertation,
*Encapsulated Models: Procedural Representations for Computer Animation*.
Stephen F. May. PhD thesis, The Ohio State University, March 1998.
go to

*http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.128.1095&rep=rep1&type=pdf*

# 8.2 Wavefront Technologies

*Portions of the following history of Wavefront was extracted from corporate historical accounts.*

*Wavefront Logo*

In 1984, Wavefront Technologies was founded in Santa Barbara, California by Mark Sylvester, Larry Barels and Bill Kovacs, who wanted to produce computer graphics for television commercials and movies. Since off-the-shelf software was not available at the time, the founders adapted their business plan to develop and market their own graphic software. Contrary to anecdotes alluding to the founders' fondness for surfing California beaches, Wavefront was actually named after the term which describes the front edge of a wave of light.

During the first year, the company's production department, headed by John Grower (later head of Santa Barbara Studios) created opening graphics for Showtime, BRAVO and the National Geographic Explorer, allowing the new and first software product, *Preview*, to be modified to meet the needs of animators. *Preview* was then shipped to Universal Studios to be used on the television series Knight Rider and to Lamb and Company for use in **pre-visualizing** and controlling a motion camera rig.

In 1985 Wavefront exhibited at its first trade show, NCGA in Dallas, Texas, and participated in the SGI booth (with Alias sitting at the next table) and sold *Preview* to NBC Television in New York, Electronic Arts (London), Video Paint Brush (Australia), Failure Analysis (Mountain View) and NASA (Houston).

In 1987 Wavefront established an office in Brussels. The Belgian government became an investor and provided capital for the purchase by Wavefront of Abel Image Research (AIR) in 1988. Ironically, in many ways AIR (founded in early 1987) was the predecessor of Wavefront, since founder Bill Kovacs was a principal software developer at Abel. This purchase dramatically increased its penetration into the Japanese market. Another irony of this is that one of the largest customers in Japan is Omnibus, who was responsible for buying and closing the Abel operation through the Omnibus “**DOA**” fiasco of 1987.

In 1988 Wavefront entered the desktop market with the *Personal Visualizer*. This software gave CAD users a point and click interface to high-end photo realistic rendering. Co-developed with Silicon Graphics, this product was eventually ported to Sun, IBM, HP, Tektronics, DEC and Sony. The strategy was to bundle the software with every system sold, then follow with module sales into the installed base. In 1989, they continued this thrust into markets beyond the entertainment industry, moving into the scientific community with the *Data Visualizer* software. This was a highly flexible product for industrial design applications worldwide and built upon Wavefront’s reputation for open systems and fast graphics interaction.

In 1990, Wavefront achieved further expansion in Asia. CSK, exclusive reseller of IBM hardware in Japan, became part owner of Wavefront Japan. In 1991, Wavefront launched the *Composer* product, which provided advanced image production for creating, enhancing and recording high-impact presentations. *Composer* would become a standard for professional 2D and 3D compositing and special effects in the feature film and broadcast/video arenas. In 1992 they introduced two new products that would have dramatic impact on the entertainment and effects industry. *Kinemation*, with SmartSkin™, was a complete 3D character animation system for creating synthetic actors with natural motion and muscle behavior. *Dynamation* was developed by Jim Hourihan (Jim received his first Academy Award for Technical Achievement for the creation of *Dynamation*), and was a powerful 3D animation tool for interactively creating and modifying realistic, natural images of dynamic events. The resulting images came from the seamless blending of behavioral data and user-specified information describing shape, color and motion. According to Hourihan, *Dynamation* was developed from a program called ‘***willy***‘ that was used by a number of LA effects houses for special effects.

In 1993 Wavefront acquired Thomson Digital Images of France (founded in 1984). TDI had innovated in the area of NURBS modeling and interactive rendering and had extensive distribution channels in Europe and Asia. Originally a partner with IBM, TDI also established a commercial production arm, which would later merge with Sogitec to become Ex Machina. TDI’s main software product was TDI Explore, a tool suite that included 3Design for modeling, Anim for animation, and Interactive Photorealistic Renderer (IPR) for rendering. (Note: Alias Maya is the result of the merger of the three packages: Wavefront’s Advanced Visualizer, Alias’s Power Animator, and TDI’s Explore.)

In 1994, they partnered with Atari to develop and market GameWare, which became the exclusive game graphics and animation development software for the Atari Jaguar system. Under the terms of the agreement, Atari used GameWare for internal content creation and advised third-party developers to use GameWare as the image and geometry-authoring tool for the new 64-bit Jaguar game system.

Dream Quest Images created over 90 visual effects sequences for the 1994 *Crimson Tide* movie using Dynamation and Composer. “Since most audience members have never experienced the environment of a nuclear submarine, it was critical to deliver a realistic virtual experience for the viewer,” said Mitch Dobrowner, digital department manager at Dream Quest. Wavefront software was also used for other blockbusters, including *Outbreak, Aladdin, True Lies and Stargate*.

In 1995, Wavefront (who was valued on the market at $119M with revenues of $24M) was acquired by Silicon

Graphics, along with Alias, for $500M to form the new Alias/Wavefront venture. It is stated that the purchase was in response to the success in the CG industry of the Canadian company Softimage.

A 1998 article titled *The First Wave: The Origins of Wavefront Software* is archived at Creative Planet and details the history of Wavefront Technologies.

**Movie 8.1** Wavefront Demo

Wavefront Demo (1986)
https://www.youtube.com/watch?v=dolXi-3BcuA

**Movie 8.2** Wavefront Demo (1988)
https://www.youtube.com/watch?v=2WU2Mckj15k

**Movie 8.3** Wavefront Engineering Demo (1988)
https://www.youtube.com/watch?v=0NY4dXRA3BM

***Movie 8.4*** *Sample animations from the 1993 Wavefront Technologies Users Group. This is Part 2. Part1 of this compilation can be seen at*

*http://www.youtube.com/watch?v=3PBH0tvZCaE*

*Note: Because of licensing restrictions from Sony Music Entertainment, the entire videos cannot be viewed on a mobile device. The following links can be used to view them on a desktop computer*

*Part 1 – http://www.youtube.com/watch?v=3PBH0tvZCaE*

*Part 2 – http://www.youtube.com/watch?v=p2qivAkzKZY*

*The First Wave: The Origins of Wavefront Software* Creative Planet Network, February 2012.

The following is excerpted from a memorial article for Bill Kovacs from Animation World Network (June 2006)

> Bill Kovacs, who co-founded Wavefront Technologies, earned a 1997 Academy Award for science and engineering innovations and who worked as a programmer on TRON, passed away last Tuesday at his home in Camarillo, California. Kovacs, who was 56, died of a stroke in his sleep brought on by a cerebral hemorrhage.
>
> In 1984, Kovacs co-founded software company Wavefront Technologies in Santa Barbara, California. He was the company's cto until he left in 1994, when the company went public. In 1995, Silicon Graphics acquired

Wavefront. Later, both firms merged with Toronto-based Alias Research to form Alias Wavefront. Wavefront's software was combined with code from Alias Research to create Maya software. Maya, of course, is now a leading computer animation tool owned by Autodesk.

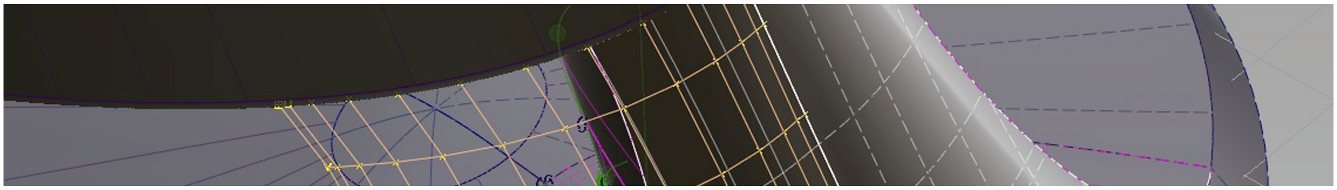
In 1997, Kovacs shared the Scientific and Engineering Academy Award with Roy Hall. The two were recognized for their work in developing Wavefront's Advanced Visualizer computer graphics system.

At Robert Abel & Associates, Kovacs was a programmer for Disney's 1982 feature, TRON, which incorporated early computer animation and paved the away for the 3D revolution.

After working for Wavefront, Kovacs was a consultant to game manufacturer Electronic Arts and Hollywood digital production company RezN8. He also was a founding partner in software startup Instant Effects.

Kovacs helped develop the School of Film and Television at Loyola Marymount University, and was its first visiting artist for technology. Recently, he lectured at UCLA and the Academy of Art University in San Francisco, where he was on the Presidential Advisory Board.

# 8.3 Alias Research



*Portions of the following history of Alias was extracted from corporate historical accounts.*

Alias Logo

The founders of Alias, Stephen Bingham, Nigel McGrath, Susan McKenna and David Springer wanted to create an easy-to-use software package to produce realistic 3D video animation for the advertising industry and post-production houses. In 1983 they came up with the idea for a software development effort to achieve this goal. Springer was teaching computer programming for designers at Sheridan College. A rare combination of artist and computer programmer, he had been working independently on software which, by coincidence, resembled McKenna's and Bingham's idea. They quickly brought him on board, and he supervised the project that involved 300,000 lines of code written in the C programming language.

Bingham was an unlikely high-tech tycoon. Lacking any formal engineering or technical training, he obtained a Master's degree in Canadian studies from Ottawa's Carleton University. He then served as the director of the city's National Film Theatre from 1980 to 1983, which allowed him to indulge in his love for movies and animation. It was a visit to Hollywood director George Lucas's renowned Industrial Light & Magic animation studios in California that inspired Bingham to form his own animation company.

Susan McKenna first got the computer itch in high school where she took Fortran. The youngest of five children, she was the first woman in the family to want to enter business with an ambition for adventure and risk. Stephen Bingham and Susan McKenna met at Carleton University in Ottawa. She spent 2 1/2 years doing administrative work in audio-video production, raising capital, writing proposals and arranging funding. McKenna approached Nigel McGrath, knowing his reputation in the industry for mixing high technology and graphic design. After high school, McGrath freelanced as a graphic artist and started McGrath & Associates in 1980 to serve major corporate clients. He kept the company while starting Alias, lending the new firm $500,000 worth of computer graphics equipment.

In 1983 they were able to obtain a $61,000 grant from the National Research Council, which, combined with the limited funds of the founders, allowed work to begin on the development of that first code, a huge undertaking that required 36 man-years of programming or 18 programmers writing for two years. Other financial support was gained from the federal government through Scientific Research Tax Credits (SRTCs). The first office, with a rent of $150/month, was located in Toronto in a renovated elevator shaft in the building that would later become the home of CITY-TV.”There were strange drafts, cold air would mysteriously fill the room, like we were in a scene from Spielberg’s *Poltergeist*,” said Susan McKenna. In 1984 the group decided on the name Alias for their new venture. “I think it was Steve who came up with the name Alias, while we were sitting in a Detroit restaurant during SIGGRAPH”, says Nigel McGrath. “You know what we need is an alias”, Steve said. “We all clicked at that point because the only paying job we had at the time was for Dave Springer to write an anti-aliasing program for a few users at SGI. That’s where the name came from”.

Alias unveiled Alias/1 at SIGGRAPH 85 in San Francisco. Alias/1 was unique because it was based on cardinal splines, producing much smoother and realistic lines or surfaces than polygonal lines. The first sale of Alias/1 was to Post Effects in Chicago followed by Editel in New York and Production Masters in Pittsburgh. Also in 1985, Alias signed a landmark deal with GM to design a system incorporating **NURBS** (non-uniform rational basis spline) technology compatible with GM’s spline based CAD (computer-aided design) system. This was the beginning of a business relationship that is still thriving today.

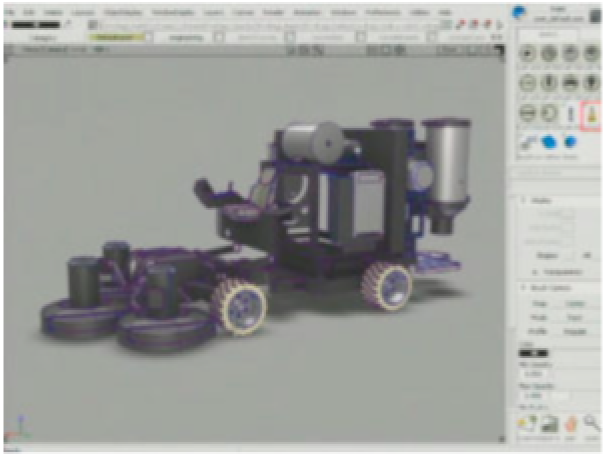
Later that year, the Alias founders approached Silicon Graphics Inc. and suggested that SGIs super-microcomputer could be used for graphic design. Until that point, SGI’s hardware had only been used for computer-aided design and computer-aided manufacturing (CAD/CAM). SGI spotted the potential for selling a computer every time Alias sold its software. These new research and development efforts required additional capital to finance the effort. Now that Alias had a big client (GM) more or less in hand, the risk was less in the eyes of potential investors. Early in 1986, Crownx, a venture capital company associated with Crown Life, invested $1.2 million for a 20% stake in Alias.

Although most of Alias sales had been to small production houses, Kraft and Motorola were added to the new client roster in 1986. Moreover, Alias managed to beat two American bidders to supply the $400,000 computer-controlled TV type equipment that would let the world watch what the Hubble Telescope could see from space. 1986 also saw the introduction of the second generation Alias/2. It had the basis spline geometry that led to the creation of the term **CAID** (computer- aided industrial design) and a whole new market. In 1987 Alias’ staff increased to 70 people with the opening of three U.S. sales offices. Concurrently, new venture capital was received from US Investors Greylock and TA Associates.

Exclusive rights to sell Alias/2 into the entertainment markets were passed in 1988 to a single worldwide reseller BTS (now Phillips BTS) who sold Alias/2 with their Pixelerator rendering machine. The Alias sales focus could remain exclusively on design opportunities, where most sales were direct except for 8 resellers in Asia. Alias boasts an impressive list of customers including Timex, Reebok. Oakley, Kenner, BMW, GM, Honda, Volvo, Apple, GE, Motorola, Sony, Industrial Light and Magic, Broadway Video and The Moving Picture Company.

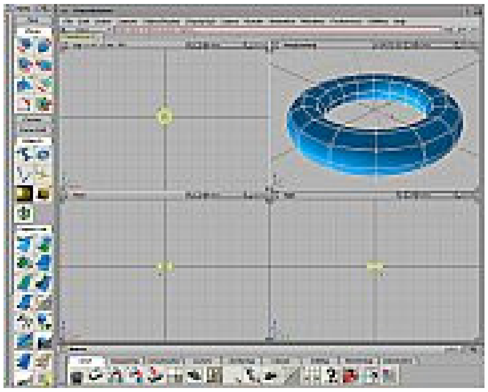
Steve Williams (ex-Alias) went to ILM to help create the pseudopod creature in the 1989 movie *The Abyss*. Alias 2.4.2 was chosen by Williams for modeling because it was patch-based (B-splines) instead of polygons. The software ran on SGI 4D/70G and 4D/80GT workstations. *The Abyss* was hailed by the film industry to be one of the most technologically advanced and difficult motion pictures ever filmed. This was proven when ILM received an Academy Award for Best Visual Effects for *The Abyss*. For the first time, Alias’ software got high-profile recognition in movie animation.

In 1989 one of Alias' most high profile industrial clients, Honda was so pleased with Alias technology that it assisted with the development of the newest version of ALIAS/2. Visiting from Japan, a Honda executive commented: "Thanks to Alias' software, we have 20 people doing the work of 200." The 1989 Honda Accord became the first car made by a foreign manufacturer to head the U.S. bestseller list. Many of Honda's cars, like those of BMW and Volvo, were designed on 3D software created by Alias.



*Alias Screenshot*

Alias raised about US$35 million in their 1990 initial public offering of 2.5 million shares. "U.S. investors understand the value of the investment better. Canadians focus on the trouble with tech stocks and not the money that's been made trading those stocks," said founder Bingham. 1990 also saw the introduction of its third generation software, branded Studio for industrial design and PowerAnimator for the entertainment market.



Alias Modeling Session Screenshot

That same year Alias client ILM reaped the highest honors for Best Visual Effects at the Academy Awards. PowerAnimator was used to create Arnold Schwarzenegger's foe, the chromium killer cyborg in *The Terminator*. Strangely enough, Schwarzeneger, who reportedly earned $12 million for that movie, was not the highest paid actor. The liquid metal man's salary worked out to about $460,000 per minute compared to $200,000 per minute for Schwarzeneger.

IBM unveiled a new line of workstations n 1990 and promoted Alias software among sales staff and customers. "Alias is the best worldwide in visualization and animation," said IBM Canada President, John Thompson. Rob Burgess, (now Chairman and CEO of Macromedia) was appointed president of Alias in 1991 with the mission to take the company to the next level of growth. Burgess announced a 3 year strategic alliance with SGI. He also seized the opportunity to purchase the Spacemaker technology and launched UpFront, a low-cost 3D Mac and Windows based package for architects. Alias achieved a major coup by impressing Bill Gates, who mentioned Upfront during a major Microsoft conference as a particularly innovative application under Windows. "In the graphics area, I picked Upfront from Alias Research. It is really an incredible tool for making sure the design is exactly right," said the Chairman of Microsoft. This project would pave the way for the development of Sketch!, positioned as a tool for graphic artists who wanted to do more realistic 3D work than could be done with Adobe Illustrator.

Alias continued to broaden its products range with the acquisition of Sonata, a high-end 3D architectural design and presentation system, from T2 Solutions of the UK. This move gave Alias four divisions covering at least five distinct marketplaces:

- Alias Division (industrial design and entertainment),
- Style! Division (Upfront and Mac/Win for architects and Sketch! on Mac for illustrators),
- Sonata Division (architecture) and
- Full Color Division (pre-press and photo retouching).

Under the direction of Burgess, Alias pushed toward its dominance of the entertainment and design markets. In the Spring of 1992, new animation features, primarily an IK (inverse kinematics) solver, were included in the fourth version of PowerAnimator. It was used to create many of the effects in Batman Returns which provided a great testimonial for Alias' return to the entertainment arena at SIGGRAPH 92. They also showed that they hadn't forgotten their design market when they introduced AutoStudio, a package specifically tailored to automotive designers. This continues Alias' focus on the transportation design sub-segment that had done very well for the company.

In 1993 Alias started the development of a new entertainment software, later known as Maya which would become the industry's most important animation tool. Steven Spielberg chose Industrial Light & Magic to provide the visual effects in 1993's *Jurassic Park*. In turn the animators at ILM picked PowerAnimator as the software of choice to model the huge prehistoric beasts. They delivered the very real looking dinosaurs with PowerAnimator and reaped the Oscar for Best Visual Effects.

Alias worked in close cooperation with Ford to develop StudioPaint, a high-end paint package designed for automotive sketching and rendering with real-time airbrushes. Rollerblade decided to purchase Alias Studio as the CAID tool of choice for their skate design after extensive benchmark testing. "Alias makes it much easier for our designers to sculpt the complex surfaces required to achieve innovative designs while meeting the constraints required for foot comfort," explained Todd J. Olson, senior industrial designer for Rollerblade Inc. Alias signed a landmark agreement with Nintendo in 1994 to be the key software tools provider. PowerAnimator was used to create *Donkey Kong Country* for Nintendo. As a result of these relationships, Alias dominated the games segment with the largest share of revenue. Alias made headlines in the Globe & Mail for helping car companies save both time and money with its industrial design software. "Detroit's auto makers are able to cut their vehicle's development time to three years from four-plus." Automotive and transportation design companies included: GM, Ford, BMW, Volvo, Honda, Toyota, Fiat, Hyundai, Isuzu, Nissan, Renault, Saab, Subaru, Caterpillar, Kenworth and Mitsubishi. In 1994, Ford became the largest StudioPaint installation in the world when it purchase StudioPaint for its revolutionary Global Studio design facility. StudioPaint allowed designers to create "digital concept sketches" using real-time pencils and airbrushes, and "digital facelift" of existing designs using retouching and real-time image transformation tools.

Alias' profits soared in 1994, primarily because of success in the movie industry. They reported a profit increase of 181% for the second quarter of Fiscal '95. Alias' PowerAnimator was used in five of the biggest movies in the summer of 1994: *Forrest Gump, The Mask, Speed, The Flintstones, True Lies and Star Trek: The Next Generation "A Final Unity"*. Alias customers in special effects included the most prominent studios, such as Industrial Light & Magic, Angel Studios, Digital Domain, Dream Quest Images, Cinesite, Metrolight Studios, Pixar, Sony Pictures Imageworks, Video Image, The Walt Disney Company and Warner Brothers.

**Movie 8.5** Alias 3D Software