THE COMPUTER MUSEUM REPORT

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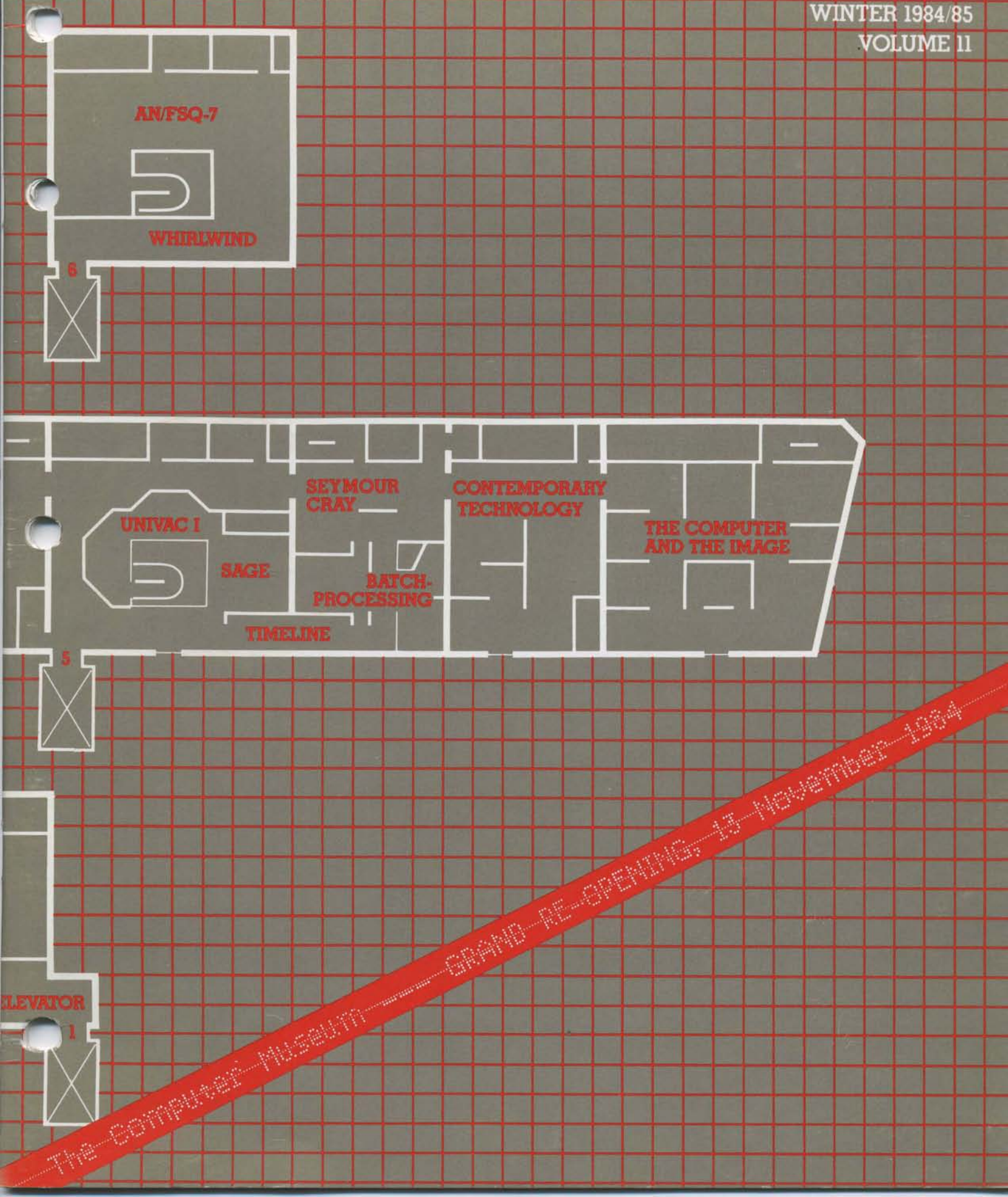

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THE COMPUTER MUSEUM

The Computer Museum is a non-profit 501(c)3 foundation that chronicles the evolution of information processing through exhibitions, archives, publications, research, and programs.

It is conveniently located minutes from Logan International Airport and just a short walk from Boston's financial district and historic landmarks such as Faneuil Hall and the Freedom Trail.

Museum Hours: The Museum hours are 11 AM–6 PM, Wednesday, Saturday, and Sunday and 11 AM–9 PM, Thursday and Friday. It is closed Mondays, Tuesdays, Christmas, New Years, and Thanksgiving.

Museum Membership: The Museum offers both corporate and individual memberships; individual membership categories range from $30.00 to $4,096.00 and Corporate Membership from $1,000 to $10,000.

All members receive a membership card, free subscription to The Computer Museum Report, a 10% discount on merchandise from The Computer Museum Store, free admission and invitations to Museum previews. For more information, contact Jana Buchholz, Membership Coordinator at The Computer Museum, 300 Congress Street, Boston, MA 02210, (617) 426-2800.

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The Computer Museum
300 Congress Street
Boston
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02210

The Director's Letter

Ed Kuge, Gwen Bell, and Masateru Takagi from Tokyo with a souvenir tape.

Ted Johnson, Massachusetts Secretary of Commerce Evelyn Murphy, Minuteman Technical High School student and robot m cutting the ribbon, Gordon Bell, Gwen ell, Bill Poduska, and John Lacey.

Visitors at the opening at the close of the tape cutting ceremony.

It's great to be open again!

About 1500 people came to the opening on November 13th, including 100 from outside of Boston. Masateru Takagi, Vice President of NEC in Japan, traveled the longest distance to represent Dr. Kobayashi at this historic event.

The formal "ribbon cutting" was in keeping with the Museum. "Shag" Graetz, who worked night and day the last week to get the PDP-1 up and running, prepared the program that punched the paper tape reading "The Computer Museum Grand Re-Opening 13 November 1984." The students at Minuteman Technical High School then programmed an Apple II to control a robot arm that cut the 1960-era tape. The new exhibitions at the Museum range from vacuum-tube computing to the uses of the new personal computers, professional workstations, and computer networks.

The re-opening and re-birth of The Computer Museum took a long time in the making. Marlboro provided an excellent beta-test site for historic exhibits but gave us little experience about interactive computing within exhibits.

After the Board of Directors approved the move in May 1983, planning started immediately. A team of "developers" was put together. Dr. Oliver Strimpel, then Curator of Mathematics, Computing, and Navigation at The Science Museum, London, agreed to come as Visiting Curator and develop a highly interactive gallery devoted to computer graphics and image processing. At the completion of this work, Oliver agreed to stay on as the Curator of the Museum. Oliver subdivided the tasks in the image gallery with Geoffrey Dutton and Andrew Kristoffy as developers.

I undertook the role of curator of the rest of the exhibitions with "developers" for each segment: Paul Ceruzzi (who is now at the Air and Space Museum) on the 1950–69 Timeline; Beth Parkhurst on the integrated circuit and Apollo Guidance Computer exhibits; Carl Sprague on the "See It Then Theatre"; Meredith Stelling on the ANFS/Q7, SAGE, and UNIVAC exhibits; Gregory Welch on the IBM 1401 Room, Seymour Cray, and Manufacturing exhibits; and Bill Wisheart on the personal computer exhibit.

Special thanks to Companies and Organizations who gave time, machines, programs, and materials to make the opening possible.

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Oliver, the developers and I then started to work with a broad set of advisors who helped us refine ideas, collect the materials and computers, and some of whom eventually worked on the actual programs and installations. The architectural firm of Crissman and Soloman were chosen to integrate the ideas of the developers with the existing structure of the 1880's wool warehouse and come up with suitable exhibition space. Meredith Stelling took on the role of supervising the contractors, Hawkins and Co., and the graphics designers, Maxwell Design.

When we worked out the schedule, all planning was to be complete by June 1, construction complete in early October, with a month for exhibit installation. It never worked that way. Everything happened at the end. And is still happening. When we opened with over half an acre of exhibits in five large rooms, each was about 70% complete. Over the winter, the exhibits will be finished and some will start to evolve even further as we watch how visitors are reacting.

By June 1, the developers had their scripts completed and then seriously sought to implement them. One exhibit that we knew we wanted to animate was on the Apollo Guidance Computer. Hewlett-Packard agreed to give us an HP-150 with a touch sensitive screen and the use of Tom Horth in their Andover facility as a consultant. Draper Laboratory's Malcolm Johnston coordinated the work of our summer intern, Andy Gerber, in order to accurately simulate the astronaut's console. But by July 1, the HP-150 had not appeared. Andy was more than ready to get started on the machine. Tom Horth came up with a loaner so that the project could begin in earnest. By mid-August the prototype program was tested and it was slow. Tom arranged to get us a faster compiler. Then, the actual machine came in September after Andy had gone back to MIT.

Another interactive exhibit that we wanted from the outset was one that communicated the concept of "discernability," conveying the meaning of pixel sizes, grey levels, and false coloring in image processing. Masscomp agreed to take on this exhibit. Lorrin Gale, Vice President of Engineering, personally made two trips to the Museum with several programmers. The project was specified and Masscomp produced a special two terminal machine. Each terminal was connected to a tv camera that they supplied. One camera is focussed on the face of the visitor, who then can change the pixel size and grey levels of his own image. The other camera is focussed on the view of Boston. The visitor can then color in the grey levels to create an "Andy Warhol-like painting." The engineers at Masscomp got excited about this project (one that has little hope of ever being a product) and kept assuring us that it would be exactly what we specified. Oliver visited it at the plant three days before opening and was satisfied. Masscomp delivered the two exhibits exactly one hour before the preview for the Board of Directors!

Last July, Oliver, Geoff Dutton and I went to SIGGRAPH, where, among other things, we collected "the teapot" from Martin Newell and got lines on other exhibit material. As I write this on New Year's Day, the "teapot" exhibit is not yet complete. Its components are numerous. Adage gave us a terminal connected via a fiber-optic cable, donated by Fibronics, to the VAX 750 contributed by Digital Equipment Corporation. The "teapot" simulation is still being programmed by Allan Sadoski, a volunteer from the Adage user group, and his 16-year old "hacker friend" Neil Day. They are spending most weekends at the Museum, providing a living, working exhibit. Parallel to this simulation, the Design and Production staff of The Children's Museum is building a stage set for the real teapot where its lighting can be manipulated manually. This should be complete in mid-winter.

IBM Fellow and Harvard Professor Benoit Mandelbrot became very excited about producing an interactive exhibit of his concept of fractals. He produced a program on the IBM XT but it lacked sufficient variation. A prolific author, he discovered, as we had, that an interactive exhibit needs to have a lot more variety than the illustrations within an article. A week prior to

opening, the program was finally acceptable but we had no machine to run on. Our two IBM XTs were committed to other programs. Dr. Mandelbrot arranged for another XT for this exhibit and it arrived (minus several critical parts) three days before the opening.

One exhibit that arrived complete and wonderful a full week before opening was a video of the view done by Dean Winkler and John Sanborn of VCA Teletronics. In August, they came up from New York and cavorted on top of the roof videotaping the view. They talked to us, looked at the logo and some of our concepts, and then spent over 200 midnight hours of editing with the very fancy frame-buffering equipment to produce a three-minute spectacular of the view popping out in different colors with the core plane logo flying over it and skyline circling a pyramid. In this case, the creators were given artistic freedom and went wild in making a very spectacular video. The equivalent spot made commercially would cost hundreds of thousands of dollars. Dean Winkler and John Sanborn will come up and explain to all how this was done in a talk on Sunday, March 17.

Yes, it's great to be open. Three "beta-test" talks were given in December, and now the full schedule of talks for the spring appears on the inside back cover. These are planned for every Thursday night at 7 and Sunday at 4 from February 7 to April 28. The next issue of the *Report* will have an article on one of the December talks—a conversation between Steve Levy and some of the heroes featured in his book *Hackers*. For those of you who can't get to the talks, we'll try to bring you the very best in the *Report*.

Best wishes for the New Year.

Special thanks to the individuals who gave their time to make the opening possible.

Frederick Ahrens
Charles Bachman
Constance Bachman
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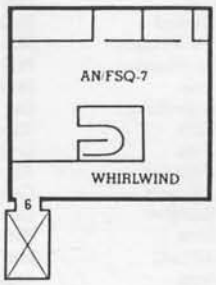
Exhibits

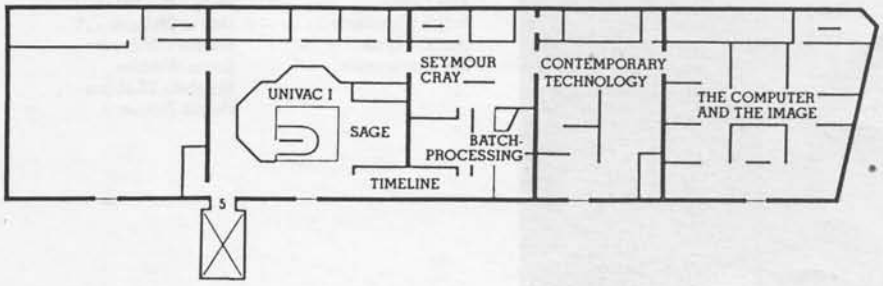
Whirlwind Entrance

The visitor enters into the Whirlwind computer—the first real-time stored program computer, so large that it took up a whole building. In a segment from a 1951 "See It Now" program, Edward R. Murrow interviews "the Whirlwind electronic computer". After he has Admiral Bolster give the "whirlwind its workout," Murrow says, "Well, I didn't understand the answer, and I didn't even understand the question." This seems really quaint to today's visitor because the whole program that the Admiral wants run on the building full of Whirlwind, is running on a Compaq that was programmed by summer student.

This first exhibit illustrates the revolution, the unbelievable power of the first computers in the early fifties, and their incredible evolution in thirty-five years. The Whirlwind occupied a building, consumed 150 kilowatts and cost as much as $20 million. The equivalent personal computer sits on a desk, plug into a wall socket, and costs two thousand dollars.

Entrance into the Museum puts the visitor in Whirlwind's arithmetic units, which occupied a whole room in the Barta Building at MIT. The 16 bit word length, extending 32 feet, was partially determined by the width of the room.





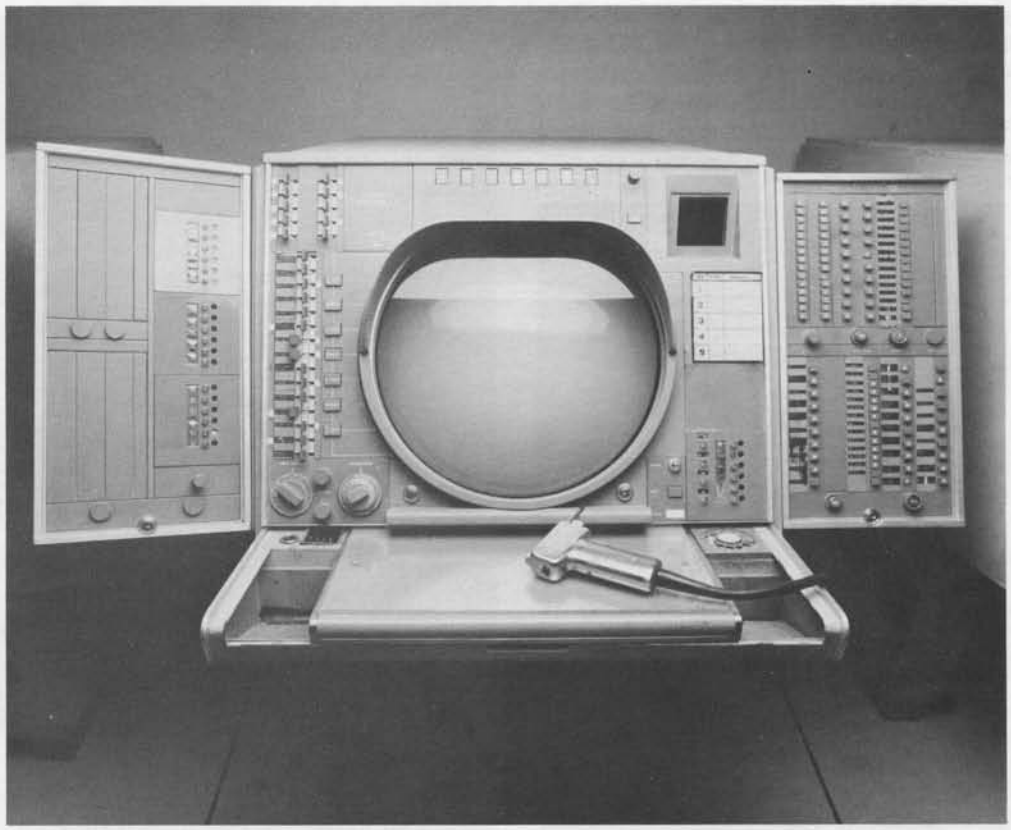
The AN/FSQ-7 and SAGE System

The Q7, a production version of Whirlwind, was probably the largest and longest lived computer in existence. It illustrates the computer components that are now on a single board or micro-chip.

The arithmetic and memory units with their 55,000 vacuum tubes took a very large space. The visitor can walk through the seven foot high banks of vacuum tubes and up to the four foot by four foot by eight foot 32-K core memory stack. The equivalent chips are exhibited and a terminal to the VAX provides a tutorial on how core memory works.

The control consoles were so large that they took up an entire room with several operators. The activities of the other components of the machine were shown in flashing lights on the consoles and the operator had a telephone to communicate with the people on the arithmetic, input-output units, or generator for the power.

The "Blue Room" consoles had large round screens that showed aircraft moving across the airspace. The screens were updated every 15 seconds by the Q7 causing a constant irritating flicker, hence a soft blue light in the room for the purpose of seeing the screen. The consoles display the air situation display and some were especially designed for weapons assignment or interception. The exhibit includes the consoles, chairs with their special drawers on the seats, and ceiling panels to recreate the feeling in the "Blue Room".



A console from the SAGE Blue Room, the control room for the SAGE, the U.S. air defense system from 1958–1983. Here, Computer Museum visitors can see the oversized video display terminals that served as the first computer graphics output devices that used light guns to identify the airplanes shown moving across the screen.

SAGE Blue Room.

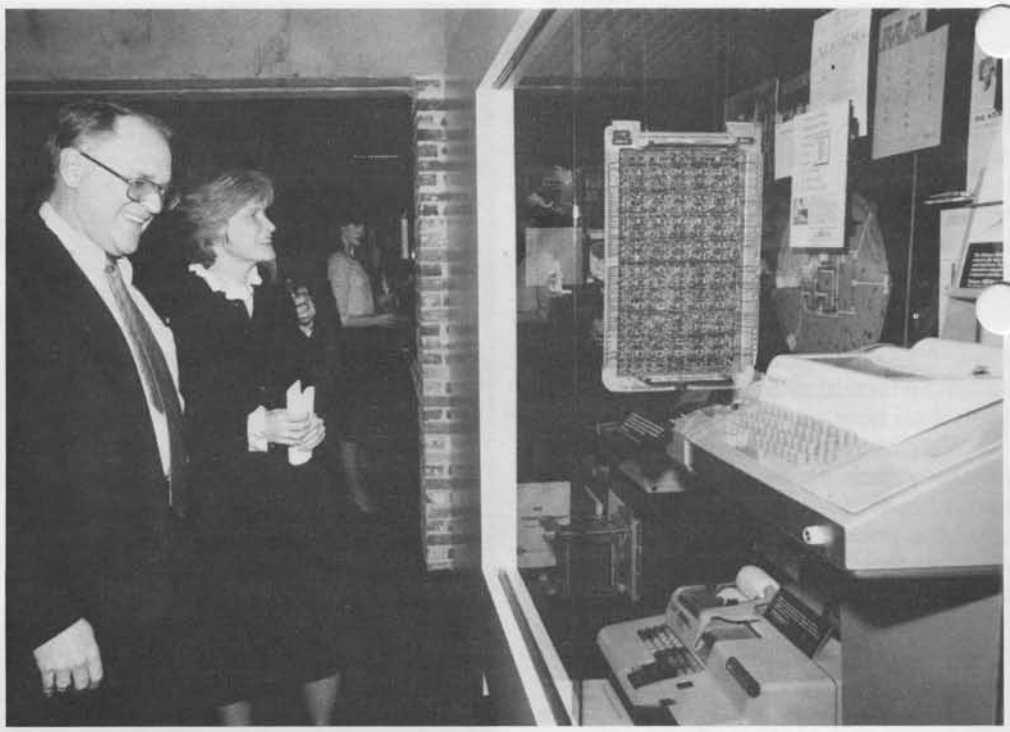
Visitors walking through two rows of the AN/FSQ-7 arithmetic unit. Each computer had 55,000 vacuum tubes with 300 changed each week for preventive maintenance, whether they needed it or not.

UNIVAC I

After UNIVAC I was featured predicting the Eisenhower election of 1952, the name almost became synonymous with "computer." The video-tape and components of a UNIVAC I bring this era back to life.

J. Presper Eckert, Walter Cronkite and Charles Collingwood with the UNIVAC on election night in 1952. At 8:30 p.m., with only a few million votes tabulated, UNIVAC's first prediction showed a landslide victory for Eisenhower. Since nationwide polls had indicated a close race, Remington Rand officials revised the national trend factor and had UNIVAC recompute. At 9:15 p.m., UNIVAC publicly predicted 8 to 7 odds for Eisenhower. By 10:32 p.m., all predictions showed that Eisenhower would decisively beat Stevenson (442 to 89 electoral votes). The president of Remington Rand went on the air to explain why they had tampered with the original prediction.

Computing from 1950–1969: A Year by Year Timeline



The first two generations of computing are illustrated in a timeline with artifacts that move the visitor year-by-year over this twenty-year span. The invention of the transistor is at the beginning and the introduction of the NOVA, a third generation integrated circuit computer at the end. Unique artifacts, such as a unit from the EDSAC and the ILLIAC I, are complemented with illustrations of new technologies, applications, and ephermal materials such as "Do not spindle" buttons.

The timeline is meant to be evocative of a walk through history. We hope that it will also bring to light many hitherto buried artifacts for preservation as part of the history of information processing.

Gordon Bell and Mass. Secretary of Commerce Evelyn Murphy looking at the early sixties section of the "Timeline." A module from the ILLIAC 2 hangs over an Olivetti Programma next to the teletype. Over 100 artifacts are included in this twenty-year timeline.

This picture of the 1969 Data General Nova and three of the company's founders, Edson de Castro, Herbert Richman, and Henry Burkhardt, ends the Timeline.

Batch-Processing in 1965:

An IBM 1401 Computer installed at The Travelers

The 1401 was the largest-selling transistorized computer. Its low price made it one of the machines which stimulated the tremendous rise in the business use of computers during the 1960's.

The exhibit is composed of three sections: the computer room, containing an IBM 1401 system; a card punch department, with an operating card punching machine which visitors can use; and a programmers office strewn with vintage programming paraphernalia.

The 1401 was designed in the mid-1950's to consolidate all of the various functions of IBM's electric punched card accounting machines; such as calculation, interpretation, collation and sorting of data. It operated on alphanumeric characters (letters and numbers) and used a variable word length. A unique feature of the 1401 was its add-to-storage feature which sped up calculation rates by eliminating the time taken for reading information from memory. The 1401 was basically intended as a card-based system, however, it was also able to use magnetic secondary memory in the form of either disc or tape.

IBM announced the 1401 in 1957 and delivered the first unit in 1958. Over 12,000 were ultimately installed. The success of the 1401 led to a small line of computers: the 1410, the 1440 and the 1460. The 1401 was the second-to-the-smallest of IBM's computers at the time. The scientifically-oriented 1620 was slightly smaller.

The principle use of the 1401 by Travelers was the generation of reports for management from information on policies issued. Information relating to policies, such as the name and address of the issuee, coverage, claims filed, etc. was stored on 80 column punched cards. Reports would be generated from these records according to a program directing which information was to be used and how, and how the result was to be presented. The speed and versatility of the 1401 permitted the condensation and manipulation of vast amounts of information into useable forms. This provided management with information about the trends in policies and claims allowing more informed decision-making.

The 1401 was a batch processing machine. Programs and data were fed to the computer one at a time exclusively by an operator. The programmer was isolated from the machine. This made the process of programming very difficult since the programmer rarely got his hands on the machine. Instead, he would encode the program he was writing, submit it to be punched from the code sheets onto 80 column cards, then have the cards delivered to the computer room with a batch of test data. The program would be run in between jobs. If it had a problem the operator would print out the contents of the memory and have them delivered back to the programmer, who would try to find his mistake and then start all over again. If the programmer was good friends with the operator, he might be able to persuade him to let him de-bug his program on the machine late at night or some other time when the machine was not busy. Programmers "drove the operators crazy" and operators "drove the programmers crazy." A film in the "See It Then Theatre" entitled "Ellis D. Kruptechev and His Marvellous Timesharing Machine" illustrates batch processing and the change to timesharing.

A visitor punching a card in the 1401 computer exhibit area.

The IBM 1401 computer room recreated as it would have been in 1964 at an installation in The Travelers Companies. Francis Hjarne and Thomas Ottman of The Travelers provided the period ephemeral material, just as 1964 World's Fair posters and wall calendars to appropriately outfit the room. One of the only criticisms is that we don't have any period crumbled up candy bar wrappers on the floor—if anyone knows the whereabouts please send them to us and we'll add to the decor.

Focus on an Individual: Seymour Cray

"Seymour Cray is the most outstanding high-performance scientific computer designer in the world."

Gene Amdahl

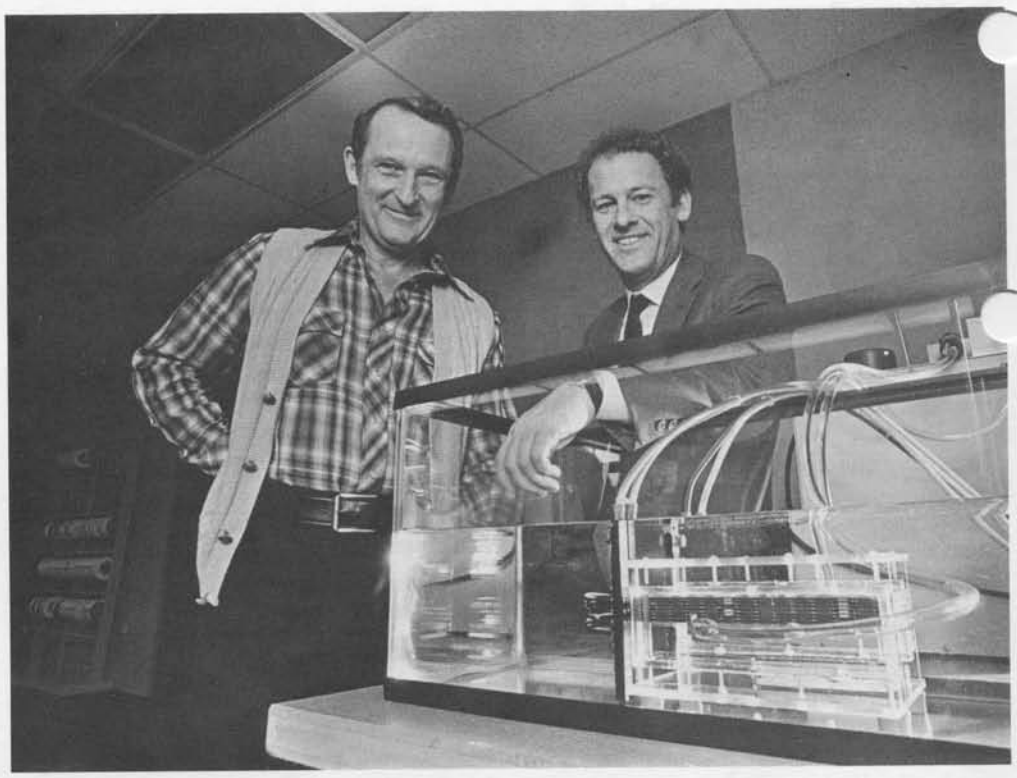
Thus, it is appropriate that Cray is the first individual that is featured in this exhibit. The intent is to change the exhibition on a yearly basis, selecting people that represent various aspects of information processing: languages, applications, entrepreneurship, and even use.

The 33-year-long career of Seymour Cray illustrates the progress of computing. He has achieved this status through practicing a unique philosophy combining a small and isolated work force, with a simple logic and circuit design. His fame and self-imposed isolation have created an aura of myth around him. The exhibit traces Cray's career by means of a combination of artifacts, photographs, and a video tape of Cray giving a lecture.

Seymour Cray was born in 1927 in Chippewa Falls, Minnesota. The son of a city engineer, Seymour exhibited an interest in science in high school. After graduating in 1943, Cray entered the military where he worked repairing radios. After WW II he went on to earn his Bachelor's degree in electrical engineering at the University of Minnesota in 1950, and a Master's in Applied Mathematics a year later. One of his professors recalls how Cray "had the almost uncanny ability to see through all the possibilities . . . and arrive at the [best] solution."

In 1951, Cray went to work for Engineering Research Associates (ERA), a Saint Paul, Minnesota computer company founded in 1946. He was instrumental in the production of the ERA 1103, which, when it was announced on February 5, 1953, was one of the first commercially-available computer systems. After Remington Rand Company bought ERA, Cray stayed on as a principle designer of the unit computer of the Naval Tactical Data System (NTDS), a weapons control system designed under contract for the Navy. The first NTDS computers, completed in late 1957, were some of the first fully-transistorized computers. Serial number one of the heavily-armoured NTDS computers is on display in the exhibit.

According to Cray, "My story really starts with the beginning of Control Data." In 1958 Cray left Remington Rand Univac to join a group of his former ERA collegues who had formed Control Data Corporation. At Control Data, Cray commenced work on a low-cost, high-speed, powerful computer for scientific computation. To test the soundness of his logic and circuit design, Cray produced the Little Character. This machine, also on exhibit, served as the prototype for Control Data's first product, the 1604 computer system, named to represent its 16 thousand words of memory and 4 tape drives. Cray continued to pursue his inclination toward the design of large and fast systems for the forefront of computing.



Seymour Cray and John Rollwagon, President and Chairman of Cray Research, stand next to a prototype of the CRAY-2. To keep i components cool, the entire CPU will be immersed in inert fluorocarbon, the substance used for artificial blood.

On August 22, 1963 Control Data announced the 6600. This computer, designed by Cray, James E. Thornton and a handfull of others in a remote laboratory which Cray had built in his home town of Chippewa Falls, was the most powerful computer of its time. It was three times faster than IBM's Stretch computer, yet a fraction of the size and cost. The 6600 exemplified many of Cray's design philosophies. For instance, its relatively small size reflects Cray's tenet that to make a computer fast one must make it compact. Half of a 6600 makes an impressive center-piece to the exhibit. On December 3, 1968 Control Data announced the successor to the 6600. The 7600 was 5 times faster than its predecessor and cost only twice as much. A set of notes on the operation of the 7600 written by Cray is enshrined in a plexiglass case in the exhibit. It encapsulates many of Cray's design philosophies; earning it the nick-name "Seymour's Bible."

In 1972 Cray left Control Data to form his own company: Cray Research Incorporated. After fours years of work, Cray Research delivered the Cray 1 to the Los Alamos National Laboratories in early March, 1976. Its radical design and $8 million price tag led some to call it "the world's most expensive loveseat." A section of the Cray 1 is on exhibit at the Museum. Above it is a large image of the computer which was generated by a Cray 1 computer, illustrating the use of the large computers for graphics and entertainment applications as well as the large-scale number crunching.

Contemporary Technology

Starting with the Apollo Guidance Computer

The Apollo Guidance Computer, developed to guide spacecraft on their journey to the moon, represents the first use of integrated circuits in computers. Designed in 1962 and 1963, when only the operator got at the computer, the astronauts defined their own user-friendly console, "DSKY." An HP-150 with a touch sensitive screen reproduces the console so that visitors can "play astronaut."

The prototype Apollo Guidance Computer (1964) and Bill Poduska, Chairman of The Computer Museum and Apollo Computer Corporation.

The Manufacture of an Integrated Circuit Computer.

The manufacture of the Data General Eclipse C330 illustrates the complex series of processes which take place in making a whole computer from its raw components. The manufacture of a computer is in many ways analogous to the final product. A series of parallel efforts, executed and coordinated on a broad scale culminate in a complete computer. The presentation includes photos, documents, and artifacts such as parts of or whole machines used in the process, and examples of the product and associated documents at each stage of development. At the end of the production line, a running Eclipse system provides the visitor with access to a data base from the International Data Group that enumerates the total of each different computer models produced year-by-year from the sixties to the present.

A large part of computer manufacturing is not robotized, but people assemble, wire and test the components that make up a machine. This photo is from a Data General prototype assembly plant in Westborough, Massachusetts.

Personal Computers: Living and Dead

A burial mound of the first three generations of personal computers is surrounded by the latest models running a variety of programs with different input-output devices.

The 1962 LINC is the representative of the first generation. Built by the users at a special course at MIT, the LINC had keyboard input, graphic output, and was portable (it could be rolled down the hall.) The 1975 Altair with the original basic tape made by Bill Gates, the Xerox Alto, and the Apple I board are three of the classics in the next generation. The Apple II, Commodore Pet, TRS-80 and others in the third.

Presently, the operational computers were selected to illustrate the uses of various input-output devices, including a mouse, touch sensitive screen, keyboard, penpad, and voice output. These computers and their programs will be constantly changed and upgraded as new and more powerful machines are introduced. The burial mound will grow as a consequence. In addition, a documentation and software library is maintained behind the scenes.

Visitors in the personal computer gallery.

The Computer and The Image

Computers' ability to manipulate and create images has changed radically in the last twenty years. Images take large amounts of memory to store, and correspondingly large amounts of computer time to process. Computer imaging of all kinds has benefitted directly from the steady decline in the cost of computer memory and processor cycles. Still most uses of computer graphics and image processing are confined to the workplace and research laboratory. For example, the animation possible on a personal computer is based on stick figures, in contrast to the 1984 two minute "cartoon" with three-dimensional figures made by Lucasfilm with the help of a Cray XMP and ten VAXes.

The image gallery both reflects the history of this application and provides a glimpse into the future. Many of the fruits of computer imaging are easily comprehended, yet are rarely seen in public. Those programs that run off the Museum's mainframes will undoubtedly be available one day on the individual workstation or home computer.

The gallery's frontispiece is a large Landsat mosaic spanning a 300 mile square region of Southern New England and New York. The image relied on digital techniques, both for its capture (there is no camera on Landsat, only an instrument that measures the brightness of one point at a time) and for its enhancement and assembly.

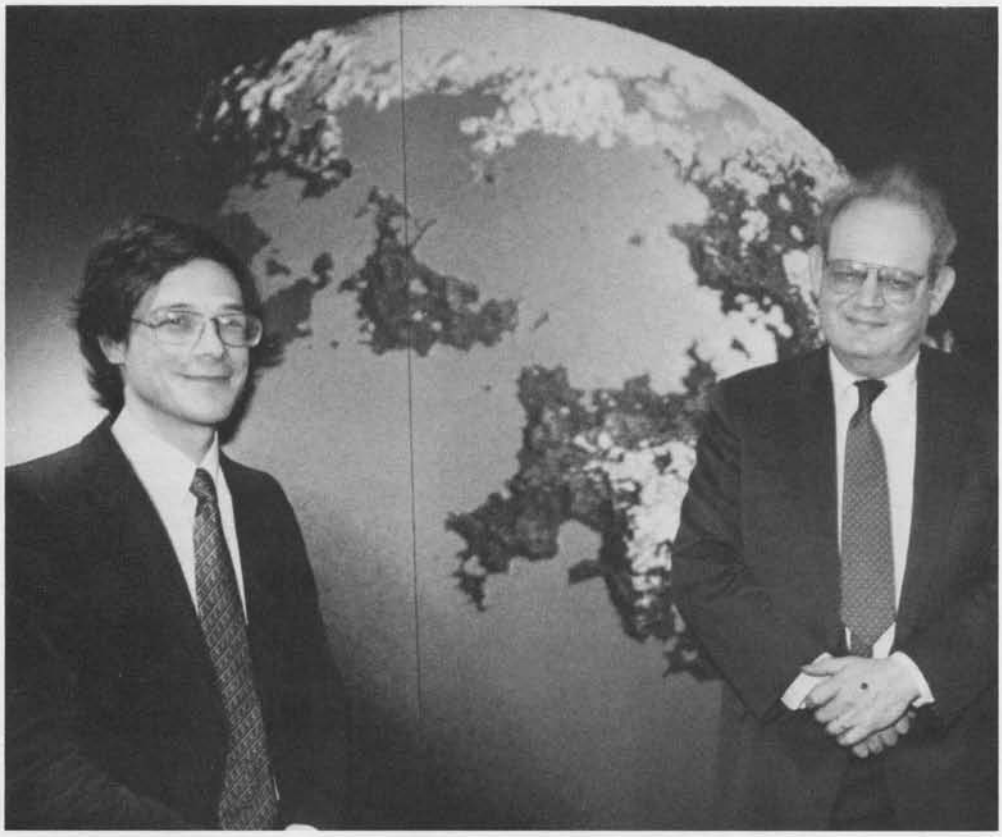
This leads into a section on image processing. Working exhibits allow the visitor to degrade the resolution and number of shades of grey on a digital image of his/her own face and pan around a Landsat picture of eastern Massachusetts showing detail down to a scale of 30 meters.

On display is the first picture of another planet taken from a vantage point in space. The data was sent back by Mariner 4 during its 1965 Mars fly-by. While the data slowly emerged from the printer, the project scientists, eagerly awaiting their first closeup view of Mars, hand color-coded and stapled up the strips of printer paper. The result looks rather like a child's painting, but does reveal some Martian craters.

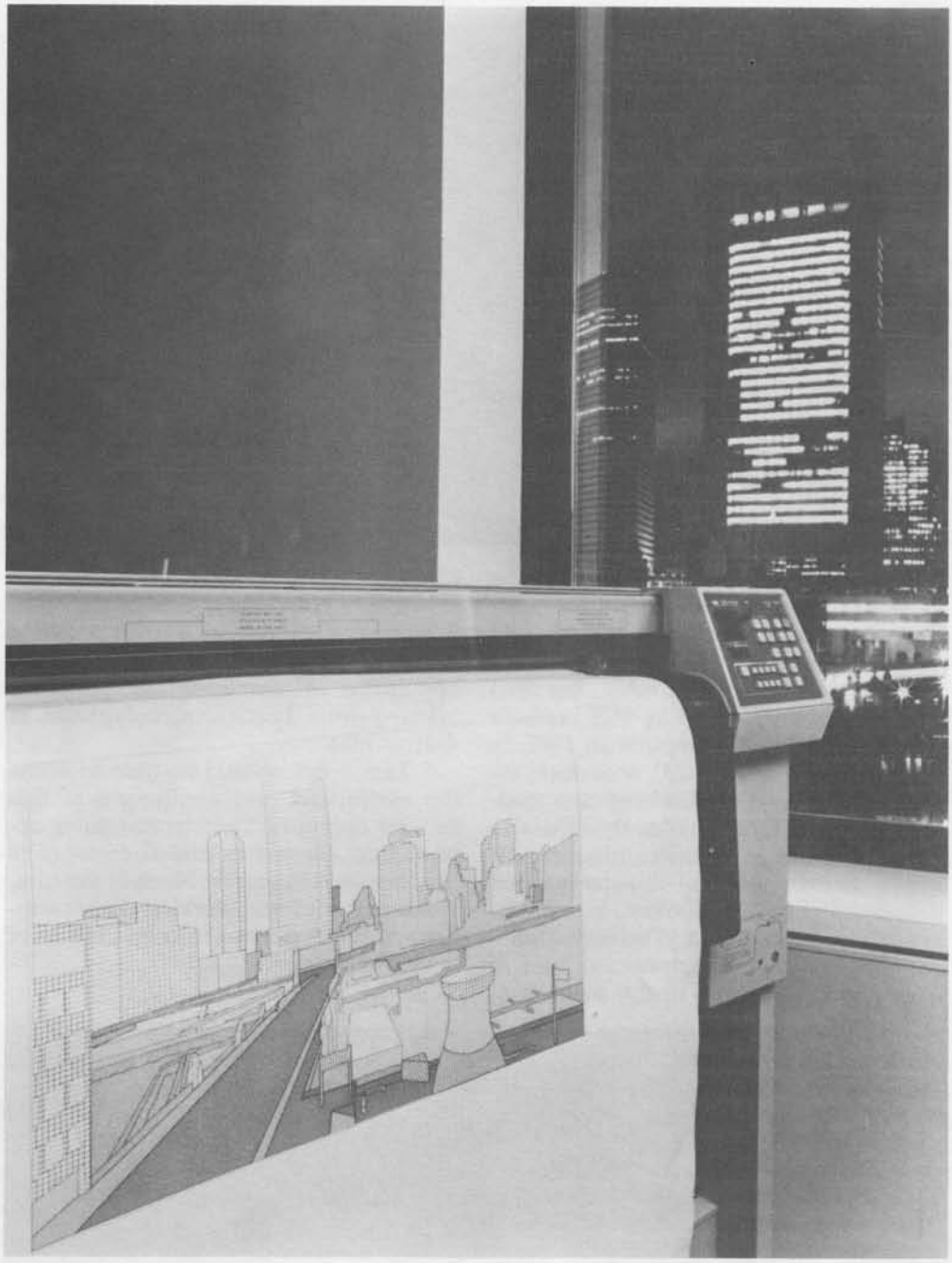
In the computer graphic technology section, two cases show graphic input and output devices. Rare items include the Rand Tablet and the crystal globe from MIT's "Kludge" terminal—one of the first geometric input devices. A video shows early graphics projects, from Ivan Sutherland's Sketchpad to the General Motors DAC-1, one of the first uses of computers in industrial design.

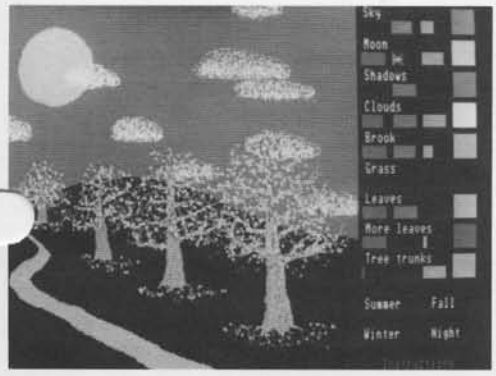
Several exhibits use the fine view

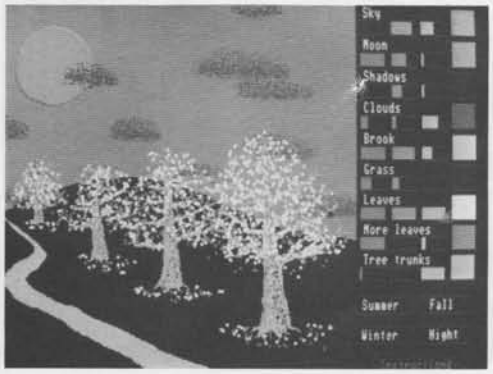
Andrew Kristoffy, Research Assistant for the gallery, first took a picture of his face. Then after it is stored in the computer, he can color each grey level differently to achieve an "Andy Warhol" look or begin to understand coloring of grey levels in order to bring out particular aspects of any image.

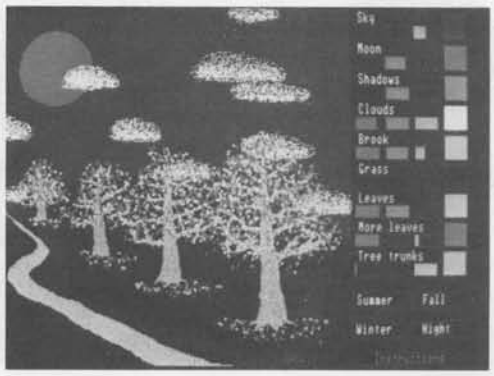


Associate Director and Curator of The Computer Museum, Dr. Oliver B.R. Strimpel, and Harvard University professor, Dr. Benoit B. Mandelbrot, also an IBM Fellow at the Thomas J. Watson Research Center, are shown standing with "Fractal Planetrise," an artificial computer generated landscape in "The Computer and the Image," a major gallery at The Computer Museum. Fractals are mathematical objects developed by Dr. Mandelbrot and have been used as models of natural phenomena such as turbulent fluid flow and the shapes of rivers and coastlines. Fractals have recently played a role in the synthesis of artificial landscapes for the film industry.









f downtown Boston from the gallery indow as a starting point: a television camera captures an image for the visitor to color in digitally, a plotter continuously draws differently colored and shaded views, and a video shows both a walk through a 3-dimensional database of the city as well as an exhilarating range of special effects applied to stretch a 2-dimensional version of the ew into "2½" dimensions.

The techniques of realistic image synthesis are shown in the section, Building an Image. Lighting, subtle color shading, the simulation of texture, transparency, reflections, and refractions of light are all shown. For many years, researchers in computer graphic realism used the data set that graphically reproduced Martin Newell's teapot to test their methods. The original teapot is now on show here in a mini stage set, next to a computer generated rendering of itself, complete with artificial colored lights. Here too you can browse through 3-dimensional computer models of houses on offer by a commercial builder.

A section on computer-aided design hows images and objects designed with the help of a machine. Examples range from parts of a Boeing 757 to an Olympic running shoe. At interactive stations visitors can design a car and complete the design of an electrical circuit. A large high precision pen plotter draws the artwork required to fabricate a microprocessor chip.

Interactive demonstrations allow the visitor to make his/her own fractals and cellular automata. Both are useful models of some natural phenomena, and rely on computer graphics for their investigation. Fractals are useful in generating artifical landscapes, several of which are shown here.

Pen plotter drawing the view from the gallery window programmed by Geoffrey Dutton for the HP 7586B connected to the VAX 750. The color and hatching denote properties such as distance, height and type of object, and are varied between one plot and the next. The drawing consists of 185 polygons which were digitized by tracing over a photograph.

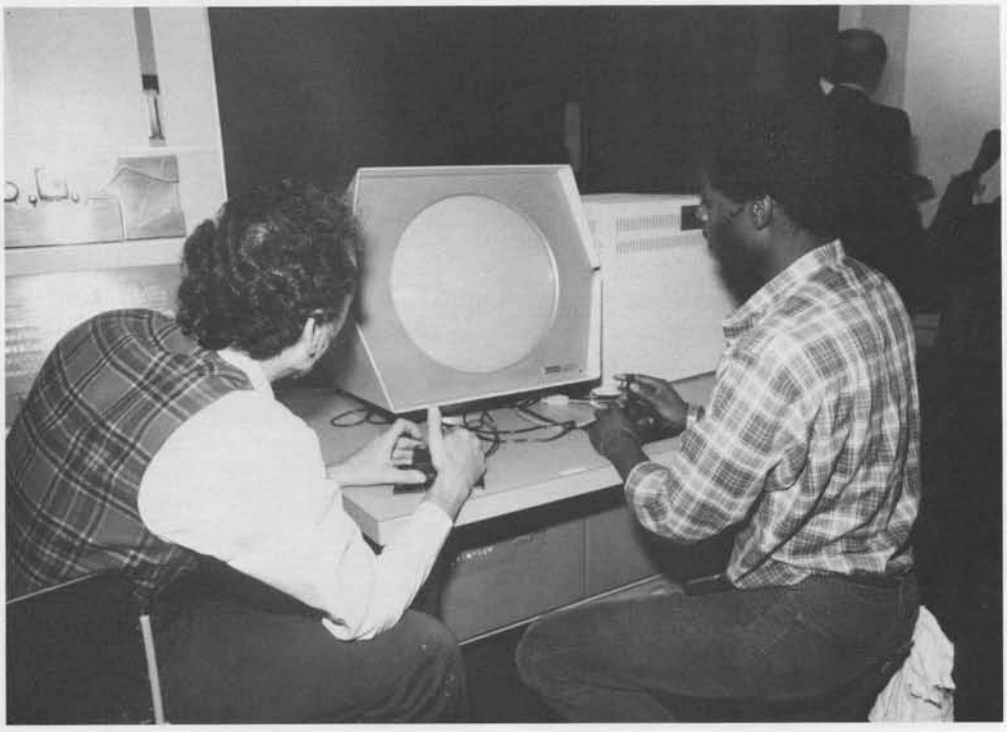
Color by Numbers! Using a mouse, the visitor can instantly re-color this landscape, selecting the season and then mixing the paint (the proportions of red, blue, and yellow) desired for each of the objects.

Eiji Kuge of NEC uses the NEC PC to simulate a pantograph. A signed nineteenth century pantograph provides the backdrop for a contemporary model that allows the visitor to understand how this drawing instrument works. Then, the scale of the same drawing can be rapidly changed using the personal computer.

In a section entitled Simulation, a video shows examples from the modelling of galaxy collisions to the interaction of a DNA molecule with a drug. The fantasy world of SPACEWAR!, the first computer game written by MIT hackers on the DEC PDP-1 computer in 1962, is demonstrated on special occasions on the PDP-1, and otherwise runs on a modern micro. Visitors can also fly a Cessna using a flight simulation program. A video shows state-of-the-art use of graphics in flight simulation, landscape synthesis, education and advertising.

Perhaps the most appealing use of computer graphics is in the making of films, both for animation and for the creation of convincing fictitious scenes. A computer animation theater shows a series of films from the earliest use of key frame inbetweening to the latest offering from Lucasfilm, completed in August 1984.

The visitor should be able to sense the excitement and challenges of this rapidly changing field in computer applications, as well as absorb many of its fundamental concepts. Much of the film, video material and working demonstrations will be updated to keep abreast of developments.



Martin "Shag" Graetz, who with Stanley Schultz and John McKenzie got the PDP-1 up and running with SpaceWar!, *plays a game with a novice.*

The Integrated Circuit: Origins and Impacts

. Robert N. Noyce

As I was driving in tonight, I was listening to a Chrysler ad pointing out that the company was 60 years old. I think of Chrysler and the auto industry as old. Then, I thought, the semiconductor business must be reaching middle age, since it is now over 30.

In 1954, the semiconductor business amounted to 25 million dollars, the growth sequence then was 35, 80, 140, 210, 360, and then 550 million by 1960. Half the business was in transistors; silicon accounted for a relatively small share.

In the fifties, everyone was trying to figure out new and better ways of making transistors. At one of the solid state circuits conferences, an explorers kit, designed to keep you from getting lost in the woods, was displayed. It consisted of a box with a small cube of germanium and three pieces of wire. If you got lost, you were to start making a point contact transistor. Whereupon ten people would lean over your shoulder and say, "That's not the way to do it." Then, you would turn around and ask, "Where am I?"

At the time, germanium alloy transistors were made by putting indium on top of semiconductor germanium and melting it just enough to dissolve some of the germanium and then recrystalizing it on both sides to make a PNP transistor.

One baffling research question was why germanium, when it was heated and then cooled in the laboratory, changed from N to P type. Simultaneously, transistors were being manufactured with N type germanium on the factory because the indium acted as a getter to pick up all the impurities instead of converting the germanium.

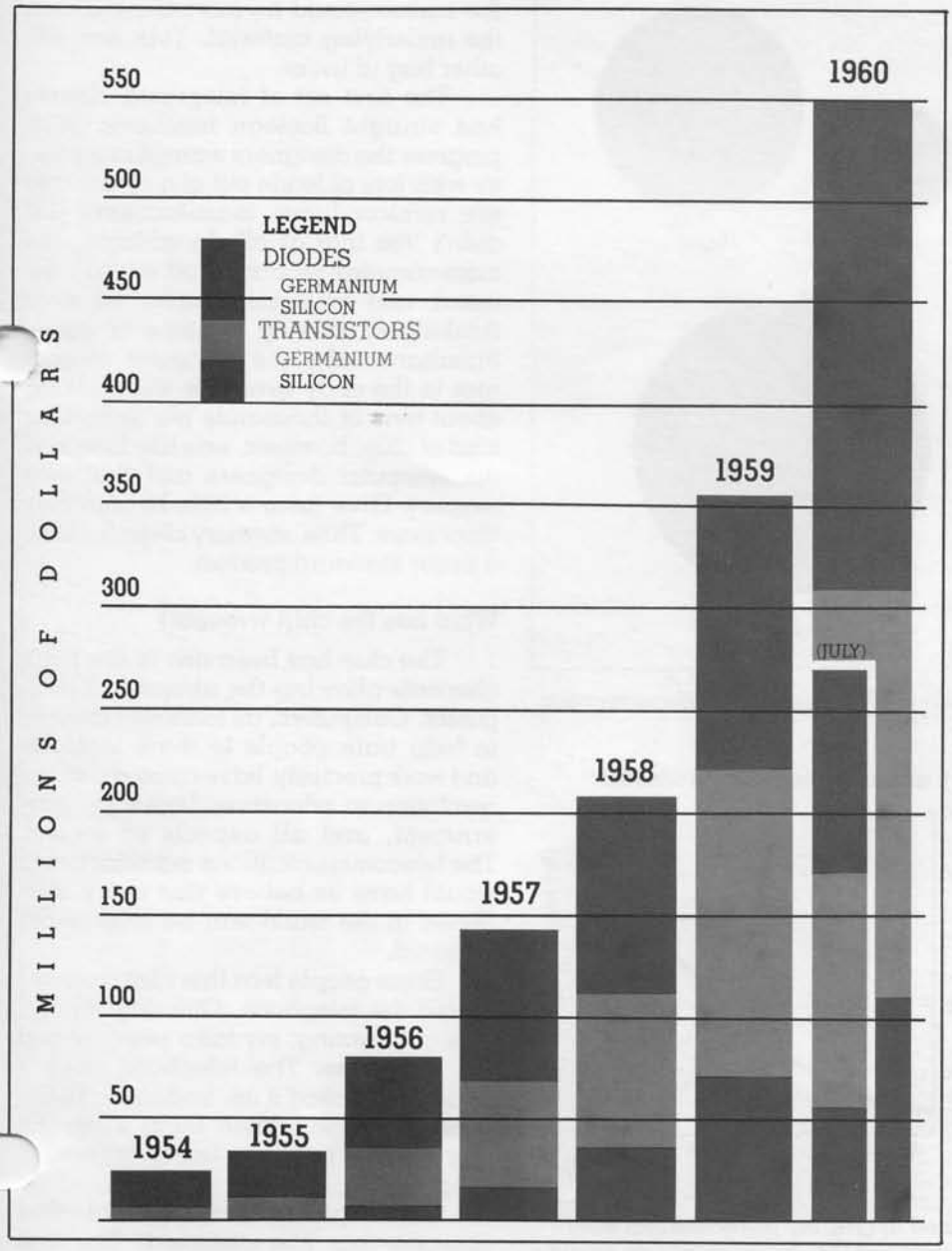
In the mid-fifties, the thinnest possible transistor was a fraction of a mil and a mil was a megacycle so these weren't very useful for anything except for hearing aids.

Between '54 and '55, we started worrying about diffusion as a way of getting impurities into the semiconductors, giving good control of the depth dimension. The problem was to get control of the other dimensions. Some of the first work was done at Philco because the semiconductor group worked right across the hall from the laboratory that was working on etching shadow mask tubes for color television. They were experienced with photo engraving, which turned out to work a lot better.

The invention of the planar transistor by Jean Hoerni further set the stage for the birth of the integrated circuit. Planar transistors solved the problem of impurities on the surface of the transistors and at their junctions that had been lousing up the specified characteristics. Hoerni's idea was to leave the silicon dioxide, a very good insulator, on top of the transistor when it was being diffused, thus forming a protective cover.

The government gave further impetus by their interest in getting things into smaller packages. The Air Force project Tinker Toy and the concept of molecular engineering didn't really work very well, but it did let everyone know that there was an interest in getting things small. A square inch chip with ten thousand transistors was very labor intensive: each transistor had to be attached by a couple of wires and soldered down. There had to be a smarter way.

I remembered that when I was in college, I could slave over something, finally get the right answer, hand in my paper and it would come back with big red markings on it. My physics professor



BREAKDOWN OF SEMICONDUCTOR MARKET

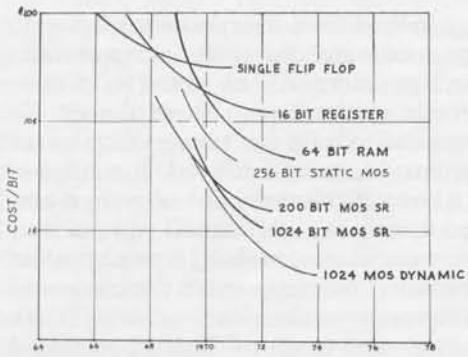
would say I did it the hard way. Then he'd jot down a couple of sentences which clearly made it much easier for me by using some other method. I guess that is what stuck with me because one of the characteristics of an inventor is that he is lazy and doesn't like to do it the hard way. Putting those 20,000 wires on 10,000 chips of silicon seemed like the hard way to me.

Although the printed circuit board was starting to be used, the thought of printing a circuit on top of the transistors had not occurred. It was the genesis of the idea of the integrated circuit. All the elements were converging: photo engraving enabled reproduction and the planar transistor allowed conductors directly on top of it. Three ideas popped up at that time. One was junction isolation, which I patented, even though it turned out that Kurt Lehovic had thought of it years before at Sprague. J. Last at Fairchild thought of the idea to etch the transistors apart, glue them down to something and if you still knew where they were you hopefully put them together. This idea had been previously patented at Bell Labs. The one I did get a patent on used intrinsic isolation, that is to use the silicon as an insulator. It didn't work well at first because by bombarding it with neutrons or doping it, leakage occurred and the life was too short. Junction isolation is now being broadly used.

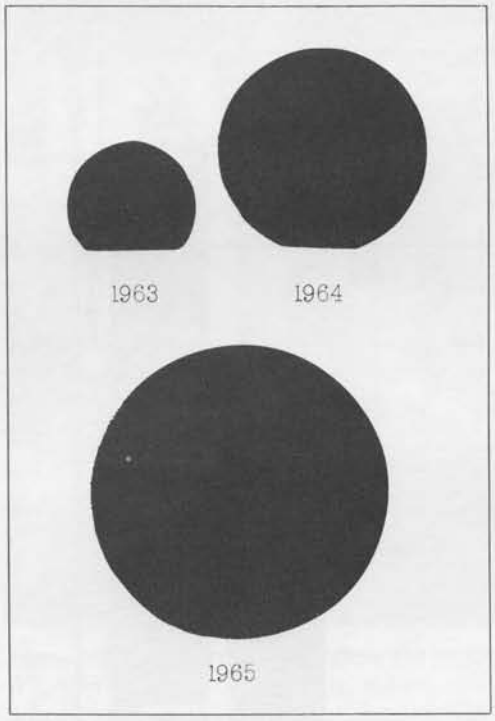
After the original concept was developed, things moved very slowly. One reason was the low yield on transistors: with 50% yield and ten transistors together, the final yield of one over two to the tenth is a small number. We didn't even consider putting a thousand transistors together. Another problem was that the early integrated circuits were very slow. And, of course, the market was opposed to this innovation.

Progress followed the classic Moore's curve. Every year you could get something twice as complex as the year before. That extrapolates to a million elements in 1980. We didn't quite make that unless you allow for the introduction of new things like magnetic bubbles. The technology also changed from bi-polar to MOS.

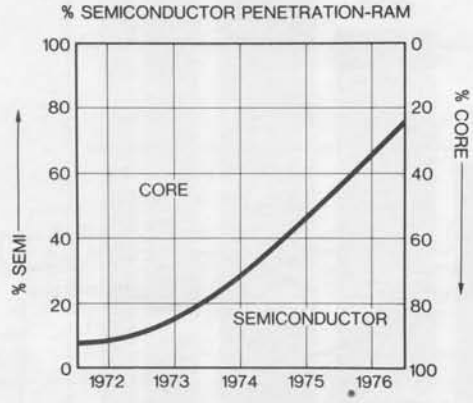
Costs are determined by complexity and the number of leads per square inch of silicon with problems setting to 20,000. Starting with a ⅝th inch wafer in 1963, costs were reduced by increasing the size to 1½ inch in '65 and two inches



Cost of semiconductor memories.



Increase in wafer size helped decrease costs.



Prepared in 1974, my prediction that semiconductor random access memories would account for 80% of the market in 1977 was on target.

in 1970. The die size and area were also increased to reduce the density of defects that would kill the surface. It became possible to use an ever increasing area to put a circuit on and have it work. Circuit dimensions themselves have been reduced below the size of neurons, 10 microns, and these are being used for speech synthesizers and other products. Today, we have two micron circuits and are talking about .7 microns, so we indeed are getting down to biological dimensions and it is conceivable to talk about things the brain can do.

Other new ideas were important. One was MOS and the second was epitaxy. Prior to the use of epitaxy, only the surface could be more impure than the underlying material. This was another bag of tricks.

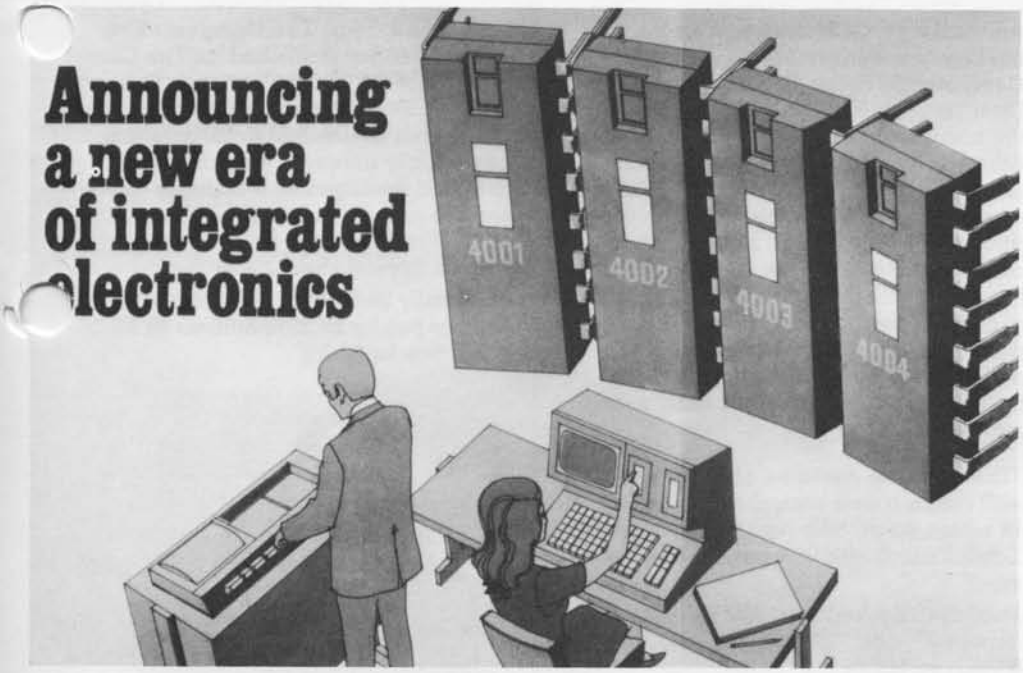
The first set of integrated circuits had straight Boolean functions. With progress the designers wanted complexity with lots of leads out of a circuit and the semiconductor manufacturers just didn't like that at all. In addition, the more complex products had a lower demand, and as manufacturers we were thinking of making millions of items. Simultaneously, the computer companies in the early seventies were talking about tens of thousands per year. One kind of chip, however, was like heroin to the computer designers and that was memory. Give them a little bit and they want more. Thus, memory chips became a major standard product.

What has the chip wrought?

The chip has been one of the main elements allowing the ubiquity of computers. Computers, as tools and devices to help train people to think logically and work precisely, have caused a major revolution in education, business, government, and all aspects of society. The telecommunications manufacturers would have us believe that every telephone in the world will be a computer terminal.

Some people fear this idea, just as I feared the telephone. One day, when I was quite young, my folks were out and left me alone. The telephone rang. I panicked, picked it up, and said, "Hello, nobody's home." Then hung it up. Today I can't imagine living without a telephone.

Let me point out a couple of other changes that I've observed. The first computer in an automobile only controlled the non-skid brake and exhaust



The microprocessor or microcomputer was introduced by Intel in 1971.

and it cost twice as much as the car and filled the whole trunk. In fact, the rear seat had to be used as well in order to install the computer. Today, computers in cars do ten times more work and cost about $30. They are less expensive than a mechanical carburetor and will pay for itself in the first year in gas savings.

Jobs in the future are not going to require the skills of the past. One-hundred-and-fifty years ago, 50% of the American labor force was employed on the farm. Fifty years ago the greatest proportion was in manufacturing. Today that is about 20%. These latest statistics are inaccurate because the categories have not changed with the economy. Intel is included in the manufacturing sector, even though only 30% of our people actually touch any products that are shipped. Most of our employees sell, keep books, or even do such useful work as design the next generation of products. Today, more than 50% of the labor force is working with information.

The computer is the major tool that can help information workers. It's a productivity enhancer for people who work with ideas as well as for people who work with things. It will allow more human use of human beings. Dull repetitive tasks are the first to go. For example, retyping a letter for one mistake, or reformatting a marketing forecast.

The tradition of liberal arts education was designed to allow people to understand and communicate in society. Grammar, rhetoric and logic came first, and then the quantitative studies of arithmetic, music with its geometrical relationships, geometry and astronomy followed. The same task is essential today. The student has new tools to help understand the continuing accelerating advances in technology. Most students will be working with a computer in some way.

It's not necessary for society to break down into C.P. Snow's two cultures in which those who do not work with technology are left behind those who have the modern tools to become productive. Despite the advances in technology, math, science and engineering are not attracting enough people in the U.S. The power of our computers that can help people as tools is growing beyond common imagination.

The Computer Museum has the CDC 6600, the first production supercomputer from 1963. It cost more than $3 million and only had 500,000 transistors. That will be available on a single chip within a couple of years and everyone can have a supercomputer. All the educational institutions have a challenge to make this work for the science and liberal arts.

FROM THE COMPUTER MUSEUM STORE

Each quarter we will be using this space to offer special gift items and recommended titles to our membership and friends.

At long last! **The First Artificial Intelligence Coloring Book** by Harold Cohen, Becky Cohen and Penny Nii.

"Teach a computer how to draw? Artist Harold Cohen does just that. Find out how by eavesdropping on an illustrated conversation between the artist and an inquisitive pair of children, sharing with them stimulating ideas about decision-making, coloring, art, and the creative process in general.

"Intellectually and visually exciting, this book is for people of all ages who are curious about creating art with computers. With 35 computer-made drawings, ready to be colored and framed."

Cloth bound, 128 pages, 9″ × 12″. Published by William Kaufmann, Inc.

On the occasion of a recent talk by the artist we asked him to autograph a limited number of copies of the book. We would like to offer these to you. $21.95 (members $19.95)

A charming gift book! **Sing a Song of Software** by Leonard J. Soltzberg.

"The first book of poems about computers, software, programs, and our complex love-hate relationship with them all. Thirty poems—illustrated with fascinating computer-generated graphics—capture both the frustration and excitement of the nerve-jangling, often funny, world of computers and computer people.

"These verses will draw a wry tinge of deja vu from computer professionals, will appeal to computer neophytes, and curious non-computer people who can all use the extensive glossary of computer terminology."

Published by William Kaufmann, Inc. Cloth bound, 7″ × 7″ (it looks just like a floppy!), 96 pages. $9.95 (members $8.95)

An insider's look at the quest for the intelligent machine! **The Cognitive Computer** by Roger C. Schank with Peter G. Childers. "This book describes the fascinating story of Professor Schank's search for the intelligent machine of tomorrow. It presents AI as an investigation into human understanding through which we learn not only about computers but about the complexities of our own intelligence. Schank's goal is to achieve cognitive understanding in computers—to create machines that will learn or change as a result of experience and be able to formulate new information.

"The cognitive computer of tomorrow will create a new computer revolution in which we all take part—and Roger Schank's research will have paved the way."

Published by Addison–Wesley. Hardcover, 6¼″ × 9¼″, 288 pages. $17.95 (members $16.15)

A best seller in The Museum Store! **Art and The Computer** by Melvin L. Prueitt.

"This book, with an introduction by Carl Sagan—written for both the novice and the professional—provides a report on some of the fine work being produced by artists using computers. It discusses problems in computer picture production, and explains how they have been solved. The book also demonstrates various methods of displaying scientific data and mathematical formulations that often turn out to be quite aesthetic."

Published by McGraw-Hill. Paperbound, 265 pages with 65 illustrations, 25 in full color. $29.95 (members $26.95)

Happy New Year! **The Computer Era 1985 Calendar** published for The Computer Museum in conjunction with Moco, Inc. A full-color, spiral bound, 13 month (December 84–December 85) calendar graphically illustrating robotics and artificial intelligence. It includes dates for 1985 scheduled computer conferences as well as important dates in computer history. Spread size: 12″ × 18″.

Originally $6.95 each, now just $4.95 each or two for $6.95 (members $4.45 each, two for $6.25)

Special Offer to readers of The Computer Museum Report: For every Museum tote bag you purchase, we will include a sturdy and handsome diskette holder. Each diskette holder will store up to three 5¼″ floppies safely and securely. Gray canvas tote with red core memory computer museum logo. Together a $17.50 value. $14.50 (members $13.05)

Hard-to-find and Rare Books! For the collector, The Computer Museum Store offers a small, but select group, of both new and used hard to find titles. Almost all are out of print. Availability varies and all are subject to prior sale. Please call the Museum Store for additional information. 617-426-2800 ext. 307.

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Thank you. Your purchases help to support the museum.

Spring 1985 Program Series

Thursdays at 7 p.m.

February 7
Mike Parker, President, Bitstream Inc.
Typography for Image-makers: Tools and Their Uses

February 14
Benoit Mandelbrot & Richard Voss, Harvard University and IBM
Fractals: How to Imitate the Mountains and the Clouds and Create Wild and Wonderful New Shapes

February 17
There will be no program; Museum will be open.

February 21
Regis McKenna, President, Regis McKenna Inc.
Marketing Technology Companies in Changing Times

February 28
Steven Wolfram, Institute for Advanced Study, Princeton University
Computation and the Complexity of Nature

March 7
Jan Rajchman, Vice President of Research Information Sciences (retired), RCA
Memories 1945–1950: The Basis of the Modern Computer

March 14
Ed Fredkin, Chairman, Fredkin Enterprises S.A.
The Billiard Ball Model for Computation

March 21
There will be no program; Museum will be open.

March 28
Charles Bachman, President, Bachman Information Systems, Inc.
Futures in Business Modeling Systems

April 4
Russell Noftsker, President, Symbolics
Artificial Intelligence: From Software Concepts to Hardware Architecture

April 11
Dr. Norman G. Anderson and Dr. Leigh N. Anderson Argonne National Laboratory
A Computerized Parts List for Man

April 18
Sherry Turkle, Massachusetts Institute of Technology
The Second Self: Computers and the Human Spirit

April 25
Alvy Ray Smith, Director of Computer Graphics Research, Lucasfilm Ltd.
Computer Graphics in the Movies

Sundays at 4 p.m.

February 10
David Nelson, Vice President of Research & Development, Apollo Computer
From the First of the High Performance Workstations to the Present

February 17
There will be no program; Museum will be open.

February 24
Martin Graetz, Alan Kotok, and Steven Russell, authors of SpaceWar!
The Making of the First Interactive Computer Video Game

March 3
Adam Osborne, President, Paperback Software International
Past, Present and Future

March 10
Keith Reid-Green, author of *Games Computers Play*
A-Maze Your Friends! How to Generate and Run Through Realistic Computer Mazes

March 17
Dean M. Winkler, Sr. Design Engineer, VCA Teletronics; & **John Sanborn**, Video Artist & Director
The Making of Renaissance: Merging Computer Graphics and Video

March 24
Alexander Schure, Chancellor, New York Institute of Technology
Computer Graphics at NYIT: Outstanding films from one of the world's leading Computer Graphics Centers

March 31
Don Lynn, D.J. Lynn Associates
Scientific Investigation of the Shroud of Turin: An Image Processing Case History

April 7
Easter: There will be no program; Museum will be open.

April 14
James F. Blinn, Computer Graphics Lab, NASA Jet Propulsion Laboratory
The Rise and Fall of Realism in Computer Graphics

April 21
Stephen Benton, Massachusetts Institute of Technology and Polaroid Corporation
Computer Holographics

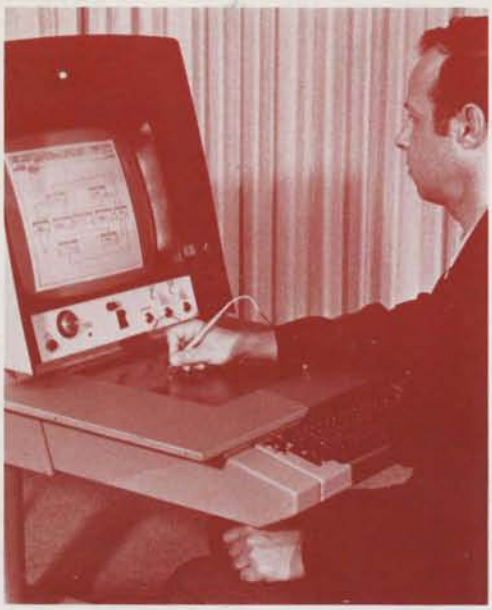
April 28
Carver Mead, California Institute of Technology
Archaeology of Electron Devices: The Origins of the Silicon Compiler

Join us for a series of informal and informative talks by the people who are making computing history – past, present and future.

All programs will take place in The Computer Museum Auditorium. Admission to the programs is free for Computer Museum members, and free to others with admission to the Museum: $4 for adults; $2 for students and senior citizens. Reserved seats are available to members by sending $2 per seat per program to Majie Zeller, Programs Coordinator, The Computer Museum, 300 Congress Street, Boston, MA 02210. Please make checks payable to The Computer Museum and clearly indicate which program(s) you plan to attend. Seats may also be reserved by paying $2 at the door up to one half hour before the program begins.

Sponsored in part by grants from the Bank of Boston and Digital Equipment Corporation.

The Computer Museum



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The Rand Tablet and Stylus, 1962

The Rand tablet was one of the first devices to allow freehand drawings to be input directly into a computer. Its pen-like stylus sensed pulses of electricity coursing through the tablet's fine grid of conductors, fixing a position to within a hundredth of an inch across the tablet's 11 inch square surface.

During the 1960's, the tablet was used for experiments in the input and machine recognition of handwritten roman and Chinese characters, as well as for interactive simulations, especially of biological systems. Many of these programs were written in GRAIL (graphical input language).

Donated by the Rand Corporation in 1984; on display in the gallery "The Computer and the Image."

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