THE COMPUTER MUSEUM REPORT

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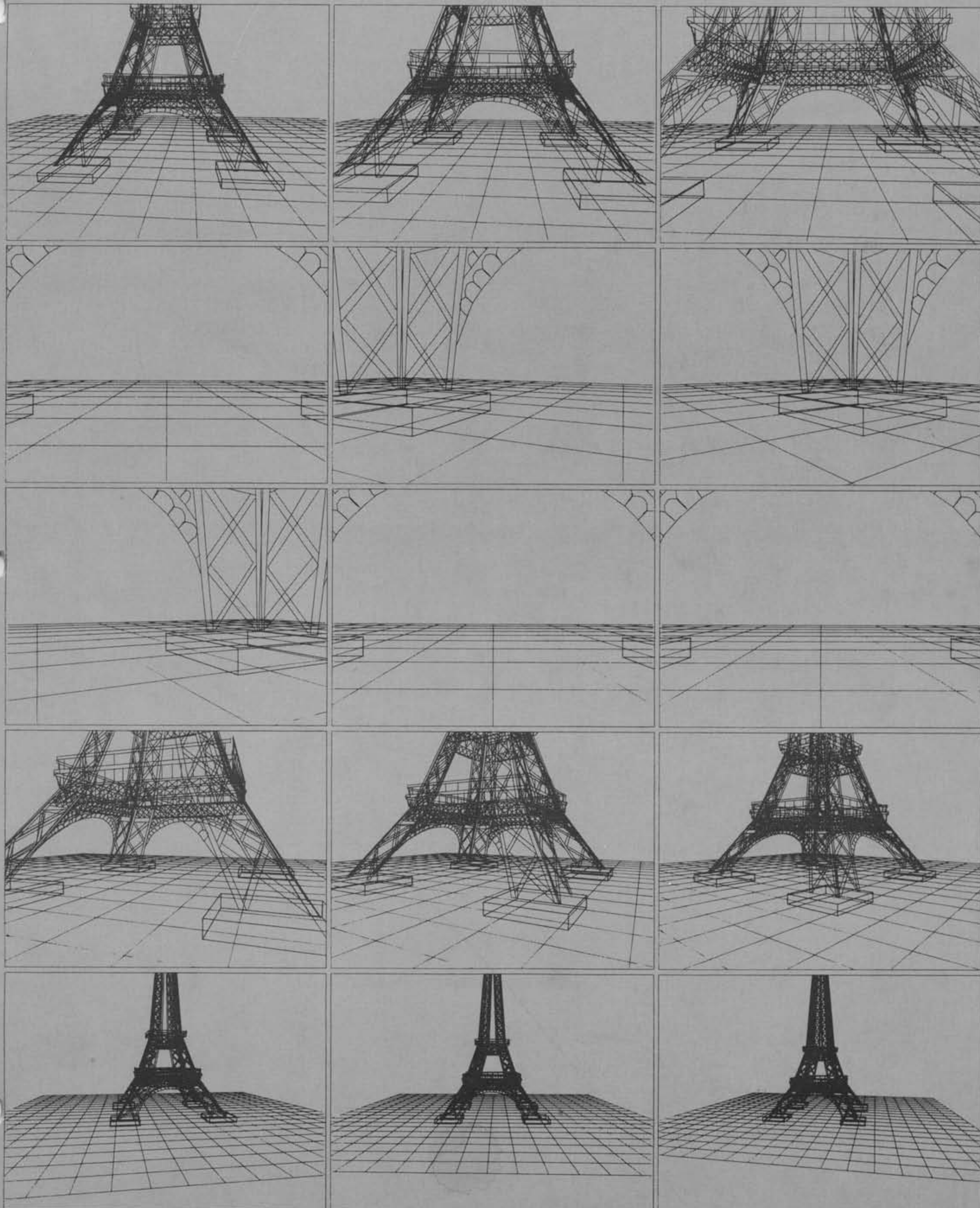

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Cover

Effie, by Keith Waters, first student place in the CalComp International Computer Art Competition. Winners on display at the Museum February 1–March 30 1986.

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.

Museum Hours: The Museum hours are 10 AM–6 PM, Tuesday, Wednesday, Saturday, and Sunday and 10 AM–9 PM, Thursday and Friday. It is closed Mondays, Christmas, New Years, and Thanksgiving.

Membership: 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 Membership Coordinator at The Computer Museum, 300 Congress Street, Boston, MA 02210, (617) 426-2800.

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The President's Letter

Dear Members,

The Museum has now been open for one year. A year in which we have learned a great deal about our potential and our members' interests. We hope to put that knowledge to work in order to serve you better: putting on a wide variety of programs; scheduling special temporary exhibitions; holding innovative fund-raisers; and offering new products in our store that let you "have a bit of the Museum" for yourself, wherever you are.

Our program series, founded to serve our membership and attract the attention of the public, has also diversified. For the Fourth of July we put on our first Computer Animation Festival and had one of our best attended afternoons ever. Our winter program series features a Thursday evening film series. A simple talk on "micromice" escalated into the first Boston Mouseathon, described by Oliver Strimpel in the first article. Museum founder Alan Frisbie from Los Angeles wandered in for a visit and ended up spending the whole day! The event turned out to be a real "crowd please" and boost for micromouseketeering. The February Kids Computer Fair brought widespread participation from schools, user groups, educational software developers and Museum enthusiasts.

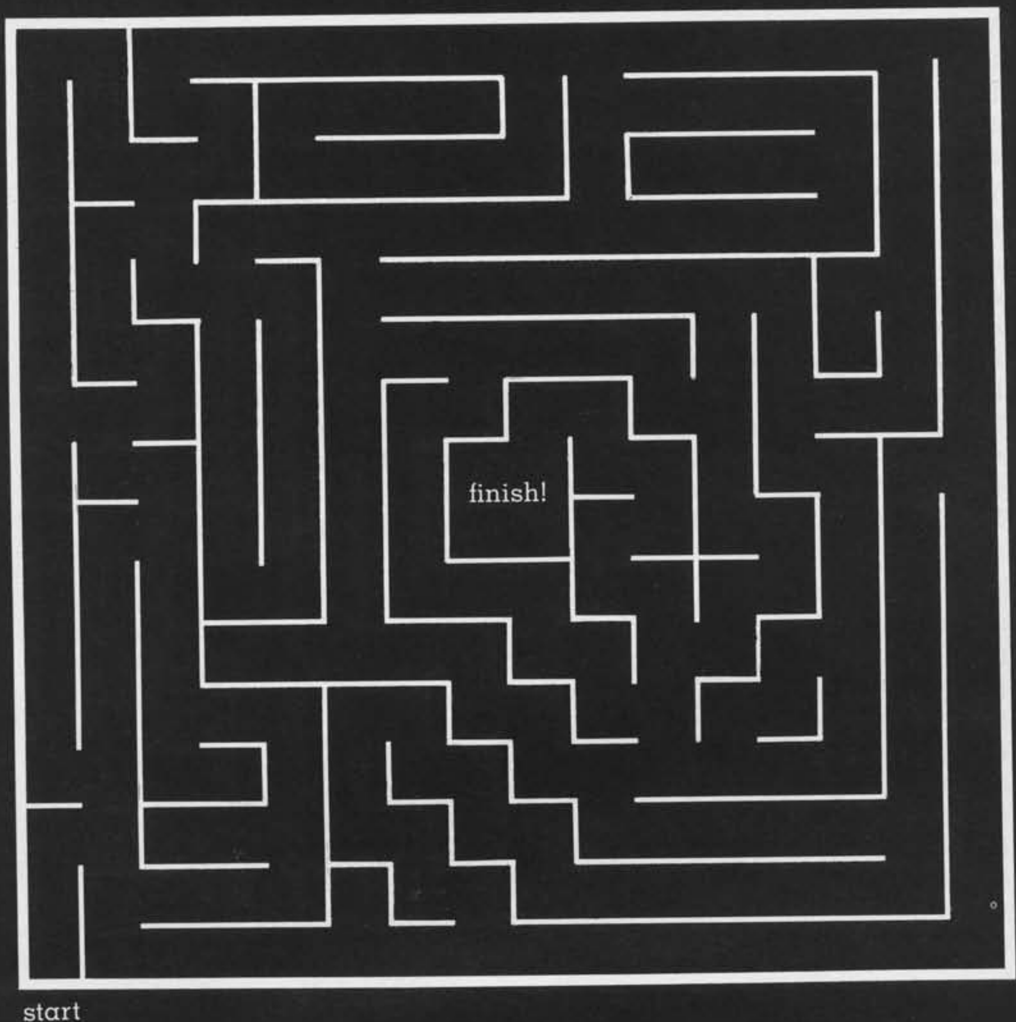
We also "fell into" doing temporary exhibitions with a show of the original artwork for BYTE magazine covers by artist Robert Tinney. This was so well received that we kept the show on display in the space near the auditorium until we could fill it with something else. It came down in mid-January in time for the January 31st opening of "The Electronic Paintbrush." The cover of this report features one of the works from this exhibition. The result of a competition sponsored by CalComp in honor of their 25th anniversary, the exhibition was first displayed at the California Museum of Science and Industry. It will be here until March 31. "Colors of Chaos," an extraordinary set of computer generated fractal images, will be on view from April 10th through June 15th. The space works for such exhibits and we welcome your suggestions for others that might be appropriate for the Museum to show.

Before we moved, the annual benefit was established. Now our fund-raising efforts have also grown and diversified. The Marlboro "yard sale" was transformed into an even more successful "attic sale" appealing to both collectors and tinkerers. In December, the Museum held "A Real-Time Event"—a truly unique fund-raiser as described later in this report issue. February's Fortieth Birthday Party for ENIAC was inspired by member Annie Roe-Hafer and heavily supported by Bitstream, Inc. a corporate member. June 8th will bring our annual gala with the Board of Directors and another chance to hear from one of them on the state of computing. Each of these events are fund-raisers and fun-raisers that appeal to different parts of the Museum's audience, and allow a great deal of interaction between members and the staff.

Finally, we have produced a videotaped version of the "See It Then" theater at the Museum. This film has gotten such good reviews for providing a quick and fun overview of the history of computing that we had to make it available, especially for everyone who teaches and can't bring their classes to the Museum. If a picture is worth 1,000 words, then this videotape is worth a 100,000 word reading assignment.

The suggestion box is open. Most of these ideas came to us from members and then they grew. In reviewing this list, it's clear to me that the Museum has an important membership. We're here because you are too.

Gwen Bell



Maze layout used in Mouseathon finals

The maze was selected to have a number of routes to the center which had similar length, but a varying number of corners. This offered a subtle test of the mouse's strategy in choosing between rapid cornering and acceleration down a straight. Note also the zig-zagging required in the final approach.

The maze consists of 16 × 16 squares, each 18cm on a side. The walls are 12mm thick, 5cm high, painted white with red tops. The target is the center, and the start is at the 'bottom left' corner. The running surface is chipboard, painted black with non-gloss emulsion paint. The walls are composed of removable segments connecting posts at the corners of the squares, so that mazes can readily be changed.

What is a Micromouse?

A micromouse is a mobile sensing robot that can negotiate a maze. The contest rules state that the mouse must be self-contained, cannot use combustion as an energy source and cannot leave part of its body behind while in the maze. It cannot jump over, climb, scratch, damage or destroy the maze walls. It must be less than 25cm in both length and width; there is no height restriction.

Most mice use active infrared sensors to locate the walls. A pulse of 1000 nanometer infrared is shone downwards from a vane that extends over the walls adjacent to the mouse. The red top of a wall sends back a strong reflection, while the black floor does not. Some mice, notably the Finnish team have used acoustic sensors. The Noriko mice used the position gyroscope as an additional sensing device to preserve accurate control during rapid cornering.

The most popular microprocessor used to control the mice is the Z80. In 1981, Alan Dibley went so far as to saw off the keyboard of a Sinclair ZX80 computer and use it intact to control his Euromicro finalist, 'Thezeus'. Indeed, the 'Thezeus' series were largely built out of bits of junk—piano wire, rubber bands (for tires), and parts from radio-controlled models.

Championship Rules *(similar to rules applied at the Museum Mouseathon)*

Each mouse has 15 minutes in the maze. It can make as many runs as it likes, and the fastest 'inward' run from the start to the center is recorded. If a mouse 'gets into trouble', it must be taken out of the maze and restarted at the beginning. No information on the maze can be fed to the micromouse. For full rules see IEEE *Micro*, Vol 4 No 6, (1984) pg 86; for information about future contests, contact Micromouse Committee, IEEE Computer Society, 1730 Massachusetts Avenue NW, Washington, DC 20036.

The Museum Mouseathon

Origins

It all began with a 1977 announcement in *Spectrum* magazine that the time was ripe for microprocessors to put on wheels for a self-controlled ride. The challenge was to build a mouse that could find its way to the heart of a maze, remember it, and then run the course as fast as possible. The IEEE Computer Society formalized the competition, specifying maze and mouse dimensions, and trials took place throughout 1978 with a final race at the National Computer Conference in 1979. The winner was the only mouse among the 24 entrants that made it to the finish! The rest of the entrants got stuck or confused, or just failed to start. But the contest looked like fun. These small mobile robots require hardware for propulsion, steering, guidance, wall and track sensing and software for mapping and strategy. The fixed set of rules constrains the problem and the contest provides a quantitative measure of progress.

International Micromouse Racing

The idea has taken off in Europe and Japan. Under the impetus of Dr. John Billingsley, mice from the UK, Finland, West Germany, Switzerland have competed in European championships held every year since 1980.

Since the first Japanese micromouse contest in 1980, the Japan Micromouse Association has grown to 800 members spread throughout the country. The association has a permanent board of directors, consisting of senior academics, industry executives and officials of the Japan Science Foundation. A bimonthly magazine 'Mouse' is published, covering micromouse events worldwide.

In 1985 the Japan Micromouse Association held a World Micromouse Contest coinciding with the World Expo in Tsukuba City, Japan. With support from the Japan Science Foundation and NAMCO Ltd., the Japan Micromouse Association invited teams from Britain, Finland, Germany, South Korea and the United States to compete. It soon became clear that the visiting mice were no match for the Japanese entrants. The first five prizes all went to mice from a single Japanese microcomputer club—the Fukuyama Club, from Hiroshima Prefecture.

Micromice in the US

Although the idea originated in the United States in 1977, it has not caught on. In 1984, in an effort to rekindle US interest, the Japan Micromouse Association presented the IEEE Computer Society with an official micromouse maze for use in the US contest where participants in the world contest would be selected. Mappy, the official mouse of the Japan Micromouse Association was loaned together with the maze. In the Spring of 1985, The Computer Museum and the IEEE Computer Society agreed to site the maze at the Museum, develop a micromouse exhibit and hold a special inaugural event.

The Museum Event

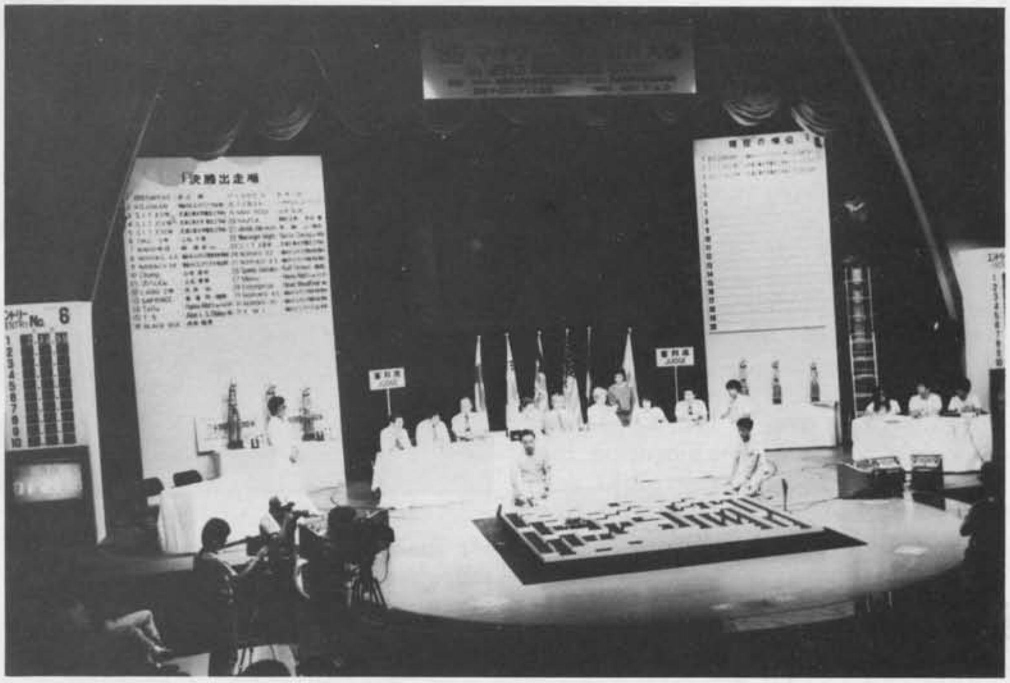
Dr. Peter Rony of the IEEE Computer Society and Dr. John Billingsley from Portsmouth, England kicked off the Museum's race week with a lecture/demonstration on Sunday, November 17. Dr. Billingsley demonstrated three mice he had brought from England.

A group from The Japan Science Foundation, NAMCO and the Fukuyama Club were also invited. Mr. Hirofumi Tashiro, Secretary General of the Japan Micromouse Association and Manager of the Director's Office at NAMCO Ltd. led the group. Three members of the Fukuyama club came: Mr. Masanori Nomura, a trained veterinarian, Mr. Masaru Idani, system technical researcher for Japan System Design Co. Ltd. and Mr. Eiichi Fujiwara. The IEEE Computer Society arranged for Mr. Key Kobayashi, an interpreter to attend.

The Inaugural Run

John Billingsley's three English mice rapidly cleared customs at Logan airport in Boston where they are used to seeing weird electronic contraptions. 'Thumper', the 1981 European champion by David Woodfield, runs on four wheels and turns by swivelling his wheels, not by rotating the whole body. His large and heavy frame tends to thump the walls, hence the name. His ability to talk, apart from being very funny, is used for diagnosis. 'T6', the latest in a series of 'Thezeus' mice by Alan Dibley, and 'Enterprise', the 1984 European Champion by David Woodfield are both three-wheeled mice with DC motors to provide propulsion on the back wheels and an optical distance counter on the steered front wheel. All three use the Z80 microprocessor.

Though delicate, the mice survived the journey intact, and they were



The 1985 World Micromouse Contest at Tsukuba *Fifteen contestants from 5 overseas countries and 120 from Japan competed.*

checked out on a trial maze. It soon became apparent that Thumper was most confused, and T6 was steering straight into the walls. Preferring not to attribute this performance to jet lag, we suspected that the maze itself was not giving the infrared signature required by the mice. The mice detect the walls by using active infrared sensors that stick out above the walls of the maze and look down. The tops of the walls are meant to be reflective in infrared (around one micron wavelength) and the black floor of the maze is meant to absorb infrared. However, the floor of the maze, though black, looked rather shiny in the infrared, so after obtaining permission from the IEEE Computer Society, we covered the maze floor with a thick coat of the mattest black emulsion we could find. Thumper and T6 still occasionally went 'blind', so we began to suspect the walls. Using Thumper as an infrared reflectometer, we found that the dull red plastic layer that covered the tops of the walls was actually a very poor reflector of infrared. So we covered all the wall tops with strips of highly infrared reflective red sticky paper, and this solved the problem.

At the start of the Sunday lecture, Peter Rony spoke on behalf of the IEEE Computer Society, presenting the Museum with the loan of the official maze, and encouraging future mouse-building activities in the US. John Billingsley then described the history of European micromouse events and demonstrated the three English mice. Thumper, though slow and lumbering, makes up for it by his speech, saying "I will find the shortest route" as he pulls off from the start. Apparently at random, he sings out with a repertoire consisting of remarks such as 'I hope there are no cats in here', 'my work is never done' and 'I could do with a rest—my wheels are killing me!' When comparing Thumper to the later mice, it's hard to believe that he is more than all talk and no action—he was actually the European champion in 1981.

Enterprise and T6 learn the maze after relatively little exploration and take advantage of the straight passages with bursts of acceleration.

The Mouseathon

After 21 hours in the air, the Japanese participants arrived late on the Thursday before the Saturday event. Refreshed the following morning, they unpacked their mice—all members of the 'Noriko' series. The older X1 and X2 performed well at once, but X3 and X4 seemed a bit worse off for the long

After a burst of speed down a straight, T6 brakes just in time to round a corner.

Mr. Tashiro watches Mappy at the maze's start *NAMCO, a large manufacturer of computerised games and toys, built 10 identical show mice in 1981 to promote interest in micromouse racing. Modelled after a popular Japanese cartoon character, Mappy plays the role of a mouse policeman, scouring every alleyway of the maze to find a troublesome stray cat. With siren blaring and baton waving, he bears down on the center of the maze where he spins around to burst a balloon with a pin mounted on his tail. Then he races back to the starting square, sirens still blaring and lights flashing, and shouts "I got 'em!" in Japanese.*

Mappy will be demonstrated regularly at the Museum while on loan from NAMCO.

travel, and needed some attention from the chief engineer, Mr. Idani.

An enthusiastic crowd of over 400 people showed up for the event. Throughout the morning and early afternoon time-trials were held. Each mouse had fifteen minutes in which to make its best run to the center (see rules box). All mice completed the maze, except for Noriko X4 which never really got going. Noriko X1 came in fastest, at 14.8 seconds in contrast to Thumper who managed to talk his way through the maze in 3 minutes. Mappy performed a couple of his noisy runs, greatly entertaining the audience.

The race's judges then took their places: Susan Rosenbaum, governing body member of the IEEE Computer Society and volunteer in charge of US micromouse activities, affectionately known as 'micromom', Gwen Bell, the Museum's president, Hirofumi Tashiro and John Billingsley.

The maze was changed to make sure that memories of the time-trial maze could not give any mouse an unfair advantage and the race then began with the mice competing in the order in which they qualified.

Noriko X4 still failed to wake up, but X3 completed a run in just over 13 seconds. Next, Thumper talked his way into the corners, so badly out of alignment that he had to be retired. T6, which must be the quietest mouse ever built, came in at 37.2 seconds. Enterprise performed reliably again, never slipping or needing any kind of adjustment. But his time of 28.1 seconds proved no match for the Japanese.

Now the two fastest Noriko's battled it out. Although the Noriko mice carry out a lot of apparently redundant maze exploration at the outset, they make up for it with speed and cornering agility once they find the shortest routes. It was breathtaking to watch the slalom as they swung aroung the final zig-zags towards the finish. Several times the Noriko's got stuck a hair's breadth from the finish and had to be carried back to the start. In the end, powered by a freshly inserted heavy duty Nicad battery pack, X1 made a lightning fast run of only 10.85 seconds, just over half a second faster than X2's best run of 11.55 seconds.

Gwen Bell awarded the prizes—silicon wafer pendants, hung around the necks of the human participants, not the mice.

The Future

The Museum will hold more races when new mice come forward to challenge the Japanese and Europeans. There are encouraging signs—several groups took notes at the races, saying they planned to build micromice with better maze-solving strategies. For those who want to try their hand at the software side of micromouse racing, NAMCO Ltd. makes a kit that can be purchased via the IEEE Computer Society.

John Billingsley is now promoting robot ping-pong, or 'robat'. Contestants mount their players at either end of a special table with controlled lighting and a mechanism to serve the ball. The players essentially consist of a bat fixed to an x-y plotter mounted vertically together with a vision system.

The Museum plans to collect micromice and provide a venue for future international sporting events!

Judges Susan Rosenbaum (left), Gwen Bell (center), and Hirofumi Tashiro with John Billingsley commentating.

IEEE Spectrum © 1985. Photographer: Malcolm Hewitt

After the award giving, from left to right: Eiichi Fujiwara, Masanori Nomura, John Billingsley, Oliver Strimpel, Masaru Idani. Mr. Idani and Mr. Fujiwara hold 1st and 3rd place winners, Norikos X1 and X3. The Noriko series employs a 'wheelchair' drive: two wheels have drive motors and steering is accomplished by driving them at different speeds. Fore and aft are wheels, castors or skids to provide stability. The newer Noriko's are DC motor driven, the older ones using stepper motors. A home-made position gyroscope with its axis mounted horizontally gives the mouse an accurate measure of how much it has turned, a critical piece of information when the wheels are liable to skid during very rapid cornering. These mice also have easily inserted ROMS, used to give the mouse different strategies, depending on the maze. ROM-swapping and tweaking of potentiometers is not allowed in European contests where a more rigorous criterion of micromouse self-sufficiency is applied.

Throughout my career as a computer designer, I have set out on explorations into the unknown. Over and over again I undertook the design of new computers without the foggiest idea of how to do it. Over the last twenty years, I was involved with three different machines at three different companies. In what follows, I have corrected all the dollar amounts for inflation so that direct comparisons can be made.

A Personal Odyssey

From the First 16-bit Mini to Fault Tolerant Computers

Gardner Hendrie

1964: The First 16-bit Mini

In 1964, three companies competed in the mini-computer market, even though the name had not yet been invented and they were called real-time control computers. DEC did $37 million in business; Computer Controls Corporation (CCC) $50 million; and Scientific Data Systems (SDS) $67 million business. SDS which grew to $134 million in the next year, was clearly the successful company of the three. Then in the late sixties, SDS was bought by Xerox for about a billion dollars and became SDX. In the sixties, Xerox disbanded this fairly expensive experiment. In 1965, CCC was purchased by Honeywell, surviving until the early seventies when it disappeared into the larger organization.

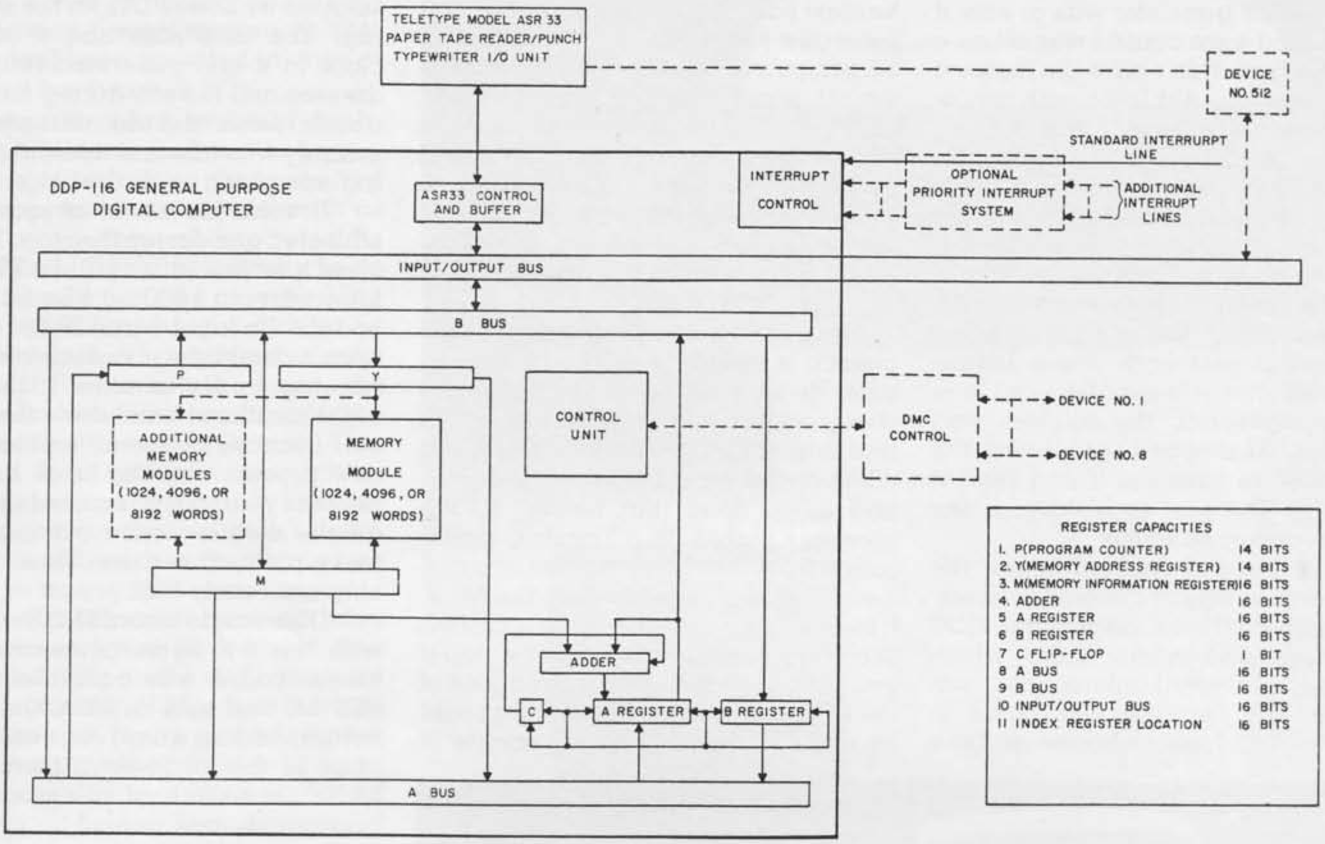
In 1964, DEC was selling the PDP-5, the precursor of the PDP-8, for $95,000. CCC was selling the DDP24, and SDS the SDS 910 and 920, each for about $300,000. The machines had 8K bytes of memory and the basic i/o device was the flexowriter, the precursor of the ASR 33 teletype which provided a keyboard, a printer, and a paper tape puncher and reader. Software existed but was not elegant. The operating systems would run on 4K words of memory and on a FORTRAN compiler with 8K words. Back-up storage was done on magnetic drums that ranged between 32,000 and a million bytes.

At that time, I had been earning a living for ten years as an engineer. My inflation adjusted salary was $65,000. If you look at salaries today they are equivalent. A VW bug cost just over $5,000. A lot of things stay the same forever, adjusted for inflation.

I had designed an industrial control computer for a division of RCA that ceased to exist two years after the computer was built. When I designed that machine, I had never designed or even worked on the design of a digital computer before, nor had I taken a course in digital computers. I did have an elementary course where I learned plug board programming on an old Burroughs machine, so I had some vague idea of the basic principles of computers. The experience was my education. The computer seems absolutely prehistoric by today's standards. It took 56 microseconds to add two 24-bit numbers and cost roughly half a million dollars. NASA used this machine for checking out the main Saturn booster stage on the Apollo missions.

Lowell Bensky, whom I had worked for at RCA when I was out of college, asked me to join CCC. The VP of marketing at CCC believed that if we could build a $75,000 computer to go along with the $300,000 DDP24, a lot more machines would be sold. I left Foxboro to build that machine for CCC. At the time, the competition was the PDP-5 and CDC's 160. In my view, the CDC 160 with its short word length, a basic instruction that could not address all of memory, and relative, indirect and chained indirect addressing, pioneered the architectural concepts that made the minicomputer feasible. It was a commercialization of Seymour Cray's first machine at CDC, The Little Character, that can be seen at the Museum and is featured in "The End Bit" of this Report.

CCC was in a good technological position to produce a competitive com-



DDP-116 General Purpose Computer, Simplified Block Diagram

puter. It manufactured a set of 5 megaherzs logic cards, each with a couple of flipflops of four or five and gates. Customers bought a card cage, plugged the cards in and then wire wrapped all of the cards together and interconnected them on the back. The company also had a memory division that built one of the more advanced devices for the time with a 1.7 microsecond cycle time. DEC's PDP-5 had a six microsecond cycle time memory and CCC's DDP 24 had a five microsecond cycle time memory. The question was—what should one build with this fast memory and circuit technology?

I became infatuated with the idea of building a fast, short-word length machine. 12 bits looked a little short. 14 bits looked just about right. It gave you enough code for a reasonable instruction set and addressing range. I didn't want to make it any longer than I had to because it would make the machine more expensive. In those days, the computer and its memory were the dominant costs not the i/o equipment. After a couple of weeks at CCC, I had an outline of the specifications.

Then, on April 26th, 1964, three weeks after I joined CCC, the bombshell hit: IBM announced the 360 and declared that the six-bit character was no longer going to be a standard for storing alphanumeric data. Instead, it would be an eight-bit unit called the byte. It didn't take much to say, "I'll bet if we increase the cost of the processor ten percent or so and lengthen the word to 16 bits we'll make up for the cost in the market appeal of a machine that can store two eight-bit bytes on the new standard just set by IBM."

By August 1964, the specs had been completed on the DDP-116. In October the machine was announced and the first shipment was in March of 1965. Only 200 were ever sold.

In 1965, CCC announced a new logic family called the Micropac using integrated circuits. These were the first commercially available integrated circuits that were designed by CCC and subcontracted to semiconductor manufacturers. The most reliable manufacturer for these flat packs was Westinghouse. CCC had also by this time designed a less than one microsecond cycle time memory.

When the 116 was shipped in March, 1965, we immediately started to work on a low cost version, the 416, and a higher cost version, the 516. Shipped in September, 1966, the 516 had a .96 microsecond cycle time and sold for $82,000. The 416 built with a hobbled 116 instruction set was supposed to cost $5,000 and sell in large quantities. While it was estimated that only 130 of the more expensive 516s would be sold. Very few 416s were ever bought, but over 2000 516s. Then a 316, lower-cost, slower machine was built to compete with DEC's lower cost 12-bit machines that seemed to be flooding the world.

After CCC was bought by Honeywell a process of decay had set in. I stayed at Honeywell working as an engineering manager and then as a product manager in marketing. Prime was formed to step into the vacuum that Honeywell left in getting out of the minicomputer market. Every machine up through the Prime 750 was object code compatible with the DDP-116 and 516.

1973: The Advent of Microprocessors

In 1973, I had the opportunity to join Data General to design a microprocessor-based computer. They had a successful 16-bit minicomputer line based on the NOVA and they wanted a NOVA on an MOS chip. My only problem with this opportunity was that I didn't know what an MOS transistor was or how it worked. And once again I was off on a new odyssey: I didn't have the foggiest idea of how you did logic with microprocessors. Otherwise, I was excited about the challenge and took the job.

The first microprocessor, Intel's 8008, a P-channel, 8-bit device, had an accidental birth. It was the outgrowth of a contract with Datapoint who had specified the architecture for a microprocessor. After the contract period had expired and both Texas Instruments (the alternate supplier) and Intel had not delivered, the contract was cancelled. TI dropped the project but Intel chose to continue it and fund it internally. The rest is history in the microprocessor business.

Data General decided to use the newest technology: n-channel processing, which produced much faster MOS transistors, and silicon gates which provided additional interconnect capability. The decision was made to build the machine in-house at DG's own semiconductor facility, which had been operational for about a year. The hardest part of designing a 16-bit computer on a single chip at a time when 8-bit computers represented the state of the art, was fitting it all onto the available area of silicon. The first decision was to use an internal 8-bit data path and arithmetic unit. I also decided to go to a serial i/o bus to solve some of the pin limitation problems. The adder would be the slowest part, even with carry predict circuits.

A second person was added to the project: a circuit designer in Sunnyvale. He showed me that registers are cheap and random logic terrible. With that information we decided to make a micro-coded machine, even though I had never done that before. In the process I picked up a Fairchild application book that had a picture of a PLA (programmed logic array) in the back. It looked like a nifty idea for instruction decoding. It also occurred to me that if you put a second PLA on the rear end of the first, all the decision making could be done by looking at the results of operations and deciding what to do next. An area efficient design was developed with two PLA's for the sequencing. The chip also had a real-time clock in it and generated refresh addresses and refresh timing for the dynamic rams during periods whe[n] memory was idle and internal processing was going on in the chip.

It took me about a year to get educated and design the chip. Then we hired a technician to build a TTL simulator who put 1,000 i.c.s on wire wrap boards. He hand wired 20,000 connections to build the simulator and had it running in six months. It then took eight months to hand draw the IC layout. Because of the difficulties of the new process and the large line size, another year was consumed in getting all the details ironed out in order to make production units. Thus, it didn't ship until early 1976.

DG's single-board $1,500 computer with the 8-K bytes of memory on a single board was equivalent to the DDP-516 that sold for $82,000 a decade before. Adding a card cage and i/o, the price of the micro-Nova increased to $8,300; one-tenth of the price of the previous decade.

1980: Fault-Tolerant Computers

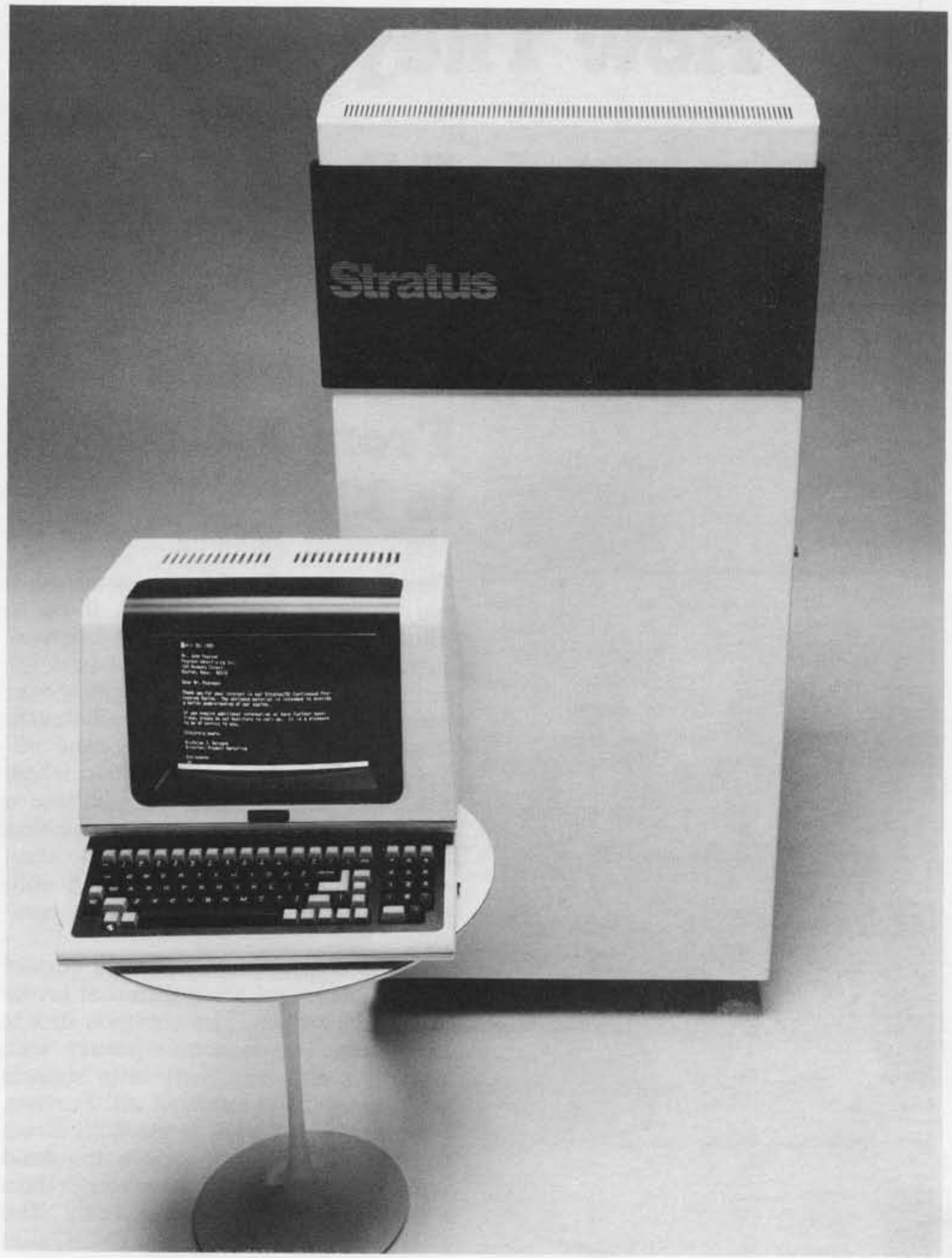
The decision to start Stratus in 1980 was based on the apparent need f[or] fault-tolerant computers in commercial on-line data processing environments as opposed to those built for scientific ones. This led to a new exploration since I didn't know anything about the subject. When I went to the MIT library, I was surprised to find volumes one through nine of the Proceedings of the Conferences on Fault-tolerant Computing oriented toward research and aerospace applications. The 1962 Apollo Guidance Computer built for NASA (that can be seen at the Museum) was a fault-tolerant machine. Only Tandem Computers had moved the technology to the commercial world.

Starting in 1974, Tandem had a 100 million dollar software intensive business by 1979. Any fault-tolerant system needs to be redundant until somebody invents parts that can heal themselves. The basic principle of Tandem was two computers side by side that could work with common mass storage. Errors are detected through memory parity or a stall alarm. A failure would restart the program at the la[st] checkpoint on the backup machine. This software intensive approach could be a major problem with many terminals involved in online data processing applications. If the system could allow some slowing down when a failure occurred, then the backup machine could be doing something useful driving normal operation. This solution had been invented in days of expensive hardware in 1974.

Stratus decided to build fault-tolerant hardware and not software. We chose a technique that required each element of the machine, such as the cpu board, to be able to detect its own failures. The simplest way to do this is to build two sets of everything and just before anything is sent out on the system bus, a comparator checks the two. If they aren't the same, the board is broken. With two boards, the work goes to the other board. This requires four sets of logic, which sounds expensive, but it isn't. I guess I should point out that we didn't figure out the scheme we used until after we raised the money for our startup.

One of the first things we did after the architecture was determined, was to put a red light on the end of a board to signal failure. Then field service didn't have to figure out what was wrong, but just take out the board and send it to the factory. Then we asked ourselves, "If field service isn't needed for fault detection, why are they needed on the customer site at all? Have the customer do it without a service call." This creates a new problem. The replacement has to be a fool proof insertion, without any special switches or an umbilical cord which might confuse the customer. In the final design, any board could be pulled out of a running machine and put in another one without anything happening.

Another problem was uncovered. How would we know what board to send to the customer for replacement? Could we depend on a secretary to pull out a bad board, read the model number, and accurately repeat it on the telephone? We thought that would be too much to ask. We added a feature that let the system read the slot location, the error state, the model number, revision level, and serial number of the bad board, finally throwing in a modem so that the computer could report the bad board directly to field service at Stratus. The electronic mail message to the Stratus computer reports what failed and all the details of the occurrence. The typical scenario is that the Stratus home office then calls up the customer and tells him that his machine has a failure. The customer doesn't know it until he's told. By then, the replacement board is on its way by Federal Express.



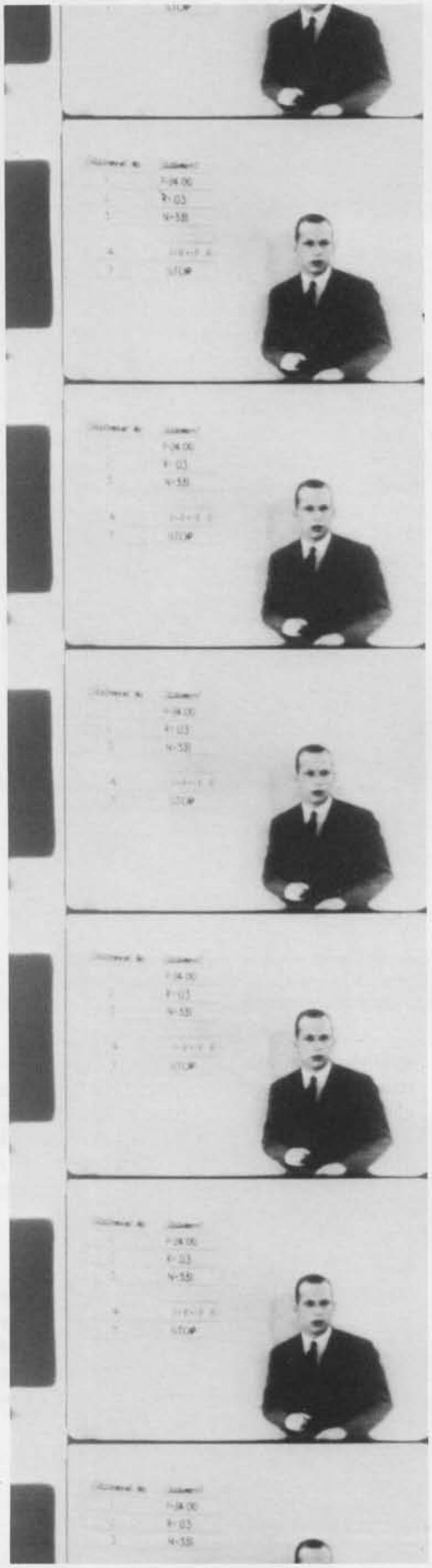
We also decided that there was no benefit in designing your own instruction set. It's fun, but a fool's errand if the objective is to make money. So we used commercially available microprocessors. We chose the 68000, the best machine in late 1979. Since we wanted to make a virtual machine, we found that the 68000 could not cope both with a page fault and restart, and at the same time go out and get a page from disk and lead it into memory. So two 68000s were put on each cpu board. The next step was to have part of the operating system run in the second 68000 in addition to the page fault handler. Then more and more processors were put in the system to run both operating system code and user code.

The second Stratus multiprocessor system has six microprocessors running concurrently out of a very large shared memory. The four microprocessor version has a .125 microsecond memory cycle time and sells for $200,000 with 4,000K bytes of main memory and a 400 megabyte disk.

A Continuing Odyssey?

It has been an adventure for me to be associated with all these computer projects. Once again I'm on a quest and will only be able to describe the avenues I explored when it is all behind me.

See How They Ran:



A Set of Classic Film Clips Showing Computing From 1920 to 1980

"See How They Ran" was assembled at the Museum and is shown there to illustrate the integration of hardware, software, other technologies and the environment of work in computing over time. Some clips were chosen because they show pioneering projects and others the flavor of the times. As a whole the film provides, in 35 minutes, a glimpse of the various components that have changed over time: size, ease of use, programming and software, and the attitude towards computers and computing.

The films were made for a variety of purposes and have different levels of sophistication. The common link is that each film is contemporary with what it is showing, very little historic interpretation is made at all. Further, all of the films were made with direct involvement of the people involved with computing at the time, rather than interpretations from other fields. The only exception is the silent ENIAC film taken in 1947, edited and narrated by Professor Arthur Burks, who was a graduate who worked on the machine, in 1981. Because of these attributes, the film has very unique pedagogical qualities—providing new insights and entertainment to trained computer professionals and the spirit of the tradition to students and interested people.

The Museum will now make this film available to others in order to serve our purpose as an educational institution.

IBM Punch Cards, 1920

This film about data processing before the computer illustrates one of its clearest antecedents.

The use of the punched card as a means of electro-mechanically storing and manipulating information was developed by Herman Hollerith for the U.S. Bureau of the Census for compiling the results of the 1890 census. The general idea of storing information on punched cards dates to the late 18th century and the use of punched cards to control the patterns woven in fabric by looms built by, among others, Joseph Jacquard. After developing machinery for the Census Bureau, Hollerith formed the Tabulating Machine Company, which later was incorporated into International Business Machines Corporation (IBM) by Thomas J. Watson. By the turn of the century several different companies were making punched card data processing systems for a wide variety of growing business uses.

The film clip shows a punched card operation of the 1920's. Women dressed in long dark skirts and white blouses transfer cards from one machine to another, and index and file them for storage. Each machine performed only one operation such as sorting cards, adding data, or printing, so the women were required to physically move the data from one machine to the next to perform a series of operations. Such systems were used through the early 1960's, when they were almost entirely replaced by computers.

ENIAC, 1946

Late at night on February 13, 1946, the legend goes that the lights dimmed at the Moore School of Engineering at the University of Pennsylvania, when the 18,000 vacuum tube ENIAC was completely turned on.

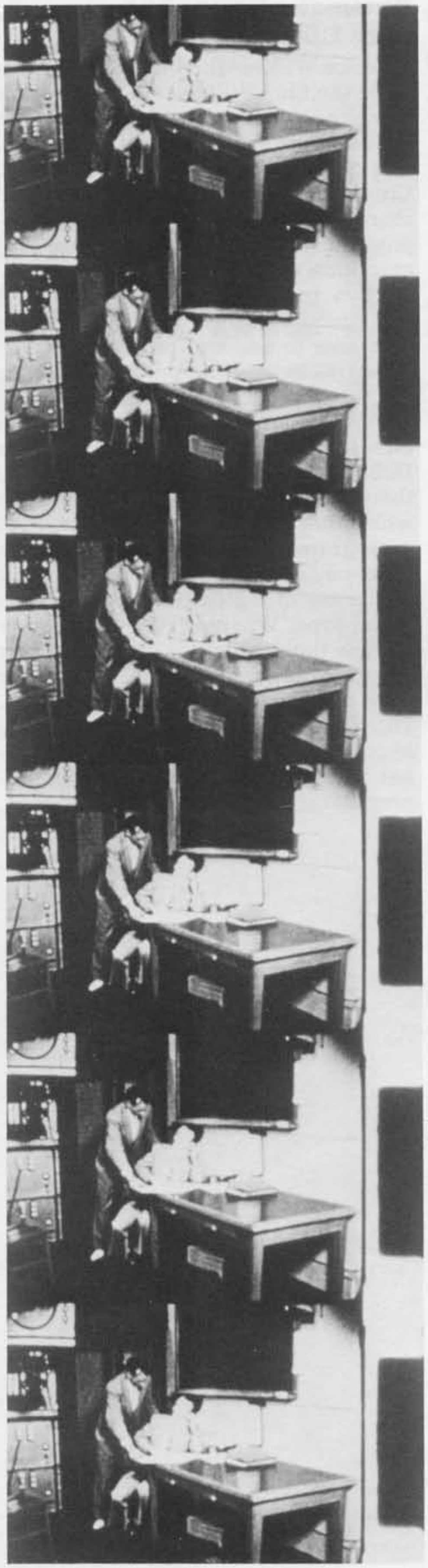
Developed by J. Presper Eckert and John Mauchly, ENIAC stood for Electronic Numerical Integrator And Computer. The group who participated in the building and use of ENIAC met to discuss the next machine. In these meetings, the concept of the stored program computer was discussed and it can be said that ENIAC led directly to the development of the stored program computer.

The film show ENIAC in use computing ballistics tables which predicted the flight of a projectile under various conditions such as the wind speed and direction, the size of the shell and firing charge, and the inclination of the gun barrel. Before ENIAC, it took several people using desk calculators many months to complete such a table for a given trajectory. ENIAC could compute the trajectory faster than real time; 20 seconds for a thirty second trajectory. However, this computation required two days of setting up the program to run on the machine. The film shows several women in knee-length skirts and bobby socks, clip-boards in hand, setting the switches on the front panel of the machine. In addition, wires had to be replugged to connect different logic components. Programming ENIAC, thus, consisted of determining how to wire the various functional components and set the dials to solve the problem.

Automatic Computing With EDSAC, 1951

Maurice Wilkes who built EDSAC narrates the film. Wilkes attended a summer school on the ENIAC held at the University of Pennsylvania in the summer of 1947, afterwhich he returned to Cambridge University in England and started to build EDSAC, the first computer in regular operation to truly incorporate the stored program concept.

Two features, illustrated in the film, made EDSAC a more efficient computer to use and program: the internal storage of the program and the use of subroutines. Maurice Wilkes says, the film "can be seen as an advertisement for subroutines." The EDSAC programmers recognized that there were certain sets of instructions which they repeatedly used. Instead of reprogramming the operations each time they used them, they kept a copy of the set of instructions encoded on paper tape. Whenever they needed to include that particular routine in their program they simply copied the master tape onto the tape of their program. This improved the speed and accuracy of programming, and was the forerunner of higher-level, more powerful programming languages.



Whirlwind I: Programming at 3:00 A.M., 1953 From "Making Electrons Count"

This film clip was produced by MIT to demonstrate the use of the Whirlwind Computer Project. During the early period of computing in the US, computers were built almost exclusively for the federal government, particularly the military. While occasionally these early computer projects were undertaken by federal agencies or private organizations, the majority were developed at universities as government projects. The universities saw the benefit of computing for a wide variety of research and educational purposes. In the film a medical research scientist learns how to program the Whirlwind to perform a calculation for optical lens design. His experience illustrates what it was like to work on an early computer: the difficulty of writing a program which worked, the separation of the programmer from the machine, and how the computer ran only one program at a time.

Both the EDSAC and Whirlwind films were used by universities to show the advantage of using computers to do very difficult problems in a research and educational environment. Prior to this time, there were common statements that three to fifty computers would be sufficient for the world's problems. These films quickly provided evidence that every university, and then every department in every university, and every research lab would be soon writing applications to justify the addition of computers.

FORTRAN, 1957

By 1954, it became clear that computing was to grow as an activity and that a scientific language was needed to ease programming. FORTRAN, short for "formula translation" was being developed then by IBM and remains an important language today.

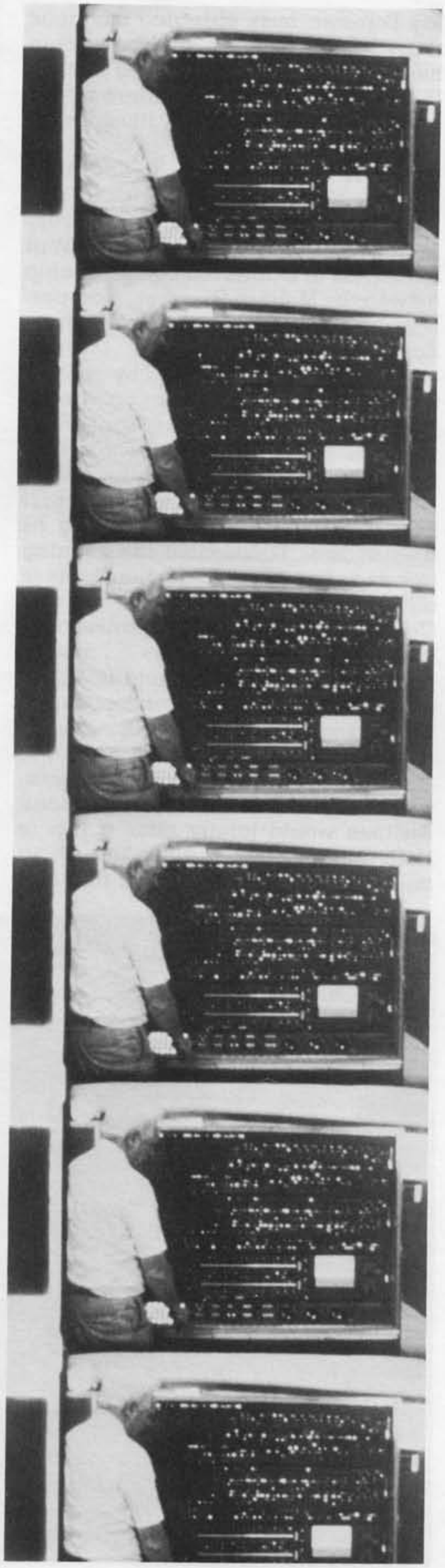
However, by 1957 it had not reached terribly wide acceptance. Many early programmers were emotionally committed to program in machine or very low-level languages. This film makes the case for programming in FORTRAN providing a very simple problem to contrast with machine language and shows a very serious advocate for this radical change.

Ellis D. Kroptechev and Zeus, A Marvelous Time-Sharing System, 1967

This student-produced film from Stanford University is a humorous spoof of the trials and tribulations of a college hacker condemned to use batch processing. Story set in the university computing center and cafeteria provides an accurate feeling for what it was like to program a computer during the 1960's.

It also illustrates an important transition from punched card batch processing computers, to time-sharing computing using teletypes and then video terminals.

Ellis D. Kroptechev is a "man with a problem, a girl and a deadline." We watch as Ellis struggles with jammed card punches, and numerous errors to complete his program in time and meet his girl friend. Ellis has to wait hours for his turn. Finally, when his program is run unsuccessfully, he must work through the listings by hand to find the errors. He cannot use the computer to assist him, in fact, he never even sees it, he can only submit his program on punched cards to the operator. In his final moments of despair Ellis is saved by Zeus, A Marvelous Time-Sharing System, in which he can directly enter the program into the computer, debug and run it himself. In no time his program runs perfectly, and in triumph Ellis walks arm in arm with his girl friend into the sunset.



STRETCH: The IBM 7030, 1960–1981

This unique film, produced for the Museum, shows one of the first supercomputers ever built.

The IBM 7030 or STRETCH as it was called was designed between 1954 to 1961 to tackle the most advanced and demanding problems of scientific computation. It embodied many technological breakthroughs, and had a great influence on later IBM machines. The concept of the "byte" versus the "bit" was developed to represent an 8-bit "syllable" of the 64-bit long Stretch word. Then in 1964, the 8-bit byte was made into a de facto industry standard with the IBM 360.

Only seven STRETCH's were ever built.

The one filmed was pieced together for the Brigham Young University computer center from the original machines from Los Alamos and from Mitre, before it was shipped to the Museum. By then it had become a dinosaur with only a 256K primary memory of 64-bit words requiring a very large room and a team of attendants.

A Real-Time Event

Gwen Bell, Michael Templeton, and Committee Member Patti Marx, dressed in their Real-Time best.

On December 7, 1985 The Computer Museum held a very special event—"A Real-Time Event." Created by Susan Poduska, the gala evening was an unusual and ambitious combination of a multi-media fashion show which told the story of the "computer era" through music, dance, slides and commentary, plus a fundraising auction which featured over 60 unique items. A real-time success, the event attracted over 200 guests and raised $35,000 for the Museum.

As searchlights criss-crossed the Museum's facade, they caught the 1956 T-Bird parked in the elevator just to set the mood. Guests mingled in the 5th and 6th floor galleries where silent auction items and bid sheets were displayed, and a sumptuous buffet was served, compliments of The Ocean Club.

The 5th floor auditorium outfitted with risers, runway and stage lights became a theater for a night. The slide show brought back the faces, fads, events, and inventions of the times, framing the models who performed vignettes choreographed to music that evoked the essence of each era. As the models swooned to "Mr. Sandman," commentators Susan Poduska and Donn Edwards told us of "Wizards and sages at MIT who were whirlwinding a new computer . . . and An Wang and Jay Forester, busy stringing magnetic rings which became known as core memory, while UNIVAC earned fame in 1952 by predicting Eisenhower the presidential winner. Many liked Ike . . . but everyone loved Lucy!"

This multi-media production brought 40 years of memories to life. Fashions were gathered from every imaginable source—from GoodWill Industries to California computer chip artwear by Melissa Panages, from personal collections to the latest from Saks Fifth Avenue.

The show was followed by another production—the Live Auction. Channel Seven news reporter Hank Phillippi as Master of Ceremonies was joined by industry stars Gordon Bell, Danny Hillis, Mike Parker, Bill Poduska and Jonathan Rotenberg as auctioneers. Throughout the evening guests bid on 45 silent auction items of all kinds. Auction co-chairs Joe and Carol Levy drew on companies and individuals from all sectors . . . restaurants, airlines, hotels, retailers and artists joined the computer community in making generous contributions to the auction. Who would have thought that Lorimar Productions, The Sheraton Corporation, and American Airlines would jointly offer a trip to Hollywood for lunch with Ana-Alicia on the set of Falcon Crest? or that Phil Cooper would offer a flight on his WWII B-25 Bomber? Portraits, theater tickets, software, hardware, catered dinners, and a talking teddy bear were just some of the many wonderful items that helped raise the $35,000 for the Museum.

"A Real-Time Event" was a major fund raiser (and fun raiser) thanks to the monumental efforts of chairperson and producer Susan Poduska, and auction co-chairpersons Carol and Joe Levy.

Their enthusiasm drew the participation of a particularly diverse and illustrious group of people all of whom gave generously of their time and th[eir] talents. We would like to take th[is] opportunity to express our deepest gratitude to the committee, the volunteers, the contributors and the museum staff—the people who made it all happen:

Bill Poduska inks in a bid for the silent auction on Liz Nolan's 'Bidmobile' while Danny Hillis (Thinking Machines Inc.), Susan Poduska, Event Chairperson and Museum Benefit Coordinator Linda Clingan look on.

PHOTOS BY ROGER FARRINGTON

The Fashion Show

Produced by Susan Poduska
Commentary by Susan Poduska and Donn Edwards
Directed by Donn Edwards, The Boston Ballet
Choreographed by—Bruce Wells,
Associate Artistic Director, The Boston Ballet
Fashion Coordinator—Pati Marx
Fashion Historian—Mary Lou Touart
Music Production—Edie Bowan, Goodtimes Music
Lighting Design—Visual Design Associates
Slide Show Production—Janet Cole
Script Research—Kate Jurow, Jurow Reynolds Associates
Stage Manager—Alexandra Lunn
Models from Copley Seven Agency
Vintage Clothing from the collections of:
Mary Lou Touart, Richard Talbot and Clemmie Lynn,
Uptown Strutters, Allston Beat
Contemporary Fashions by Saks Fifth Avenue
"Fashions that Inspire" by Le Chateau
Computer Chip Artwear by Melissa Panages

The Committee and Supporters:

Connie Bachman
Mary Baldwin
Gwen Bell
Linda Bodman
The Boston Computer Society
Linda Clingan
Caroline Collings
Cricket Press
[illegible]ice Del Sesto
Louise Domenitz
Ann Everett
Joyce Fredkin
Richard Friedman
Wendy Germain, Germain DRK
Carol Gilbaugh
Gourmet Caterers
Annie Roe-Hafer
Robert Hafer
Jack Hodgson
Anne Jenckes
Ben Kalica
Kathy Keough
Tom Labsley
Tim McNeill
Mary McKenney
James L. McKenney
Susan Parrish
Hank Phillippi
Ed Touchette, Graphic Designer
Emily Weiss
Bill Wisheart
Doris Yaffe, Saks Fifth Avenue
Matt Young, The Ocean Club, Cambridge

The Following Individuals and Companies Made Generous Auction Contributions

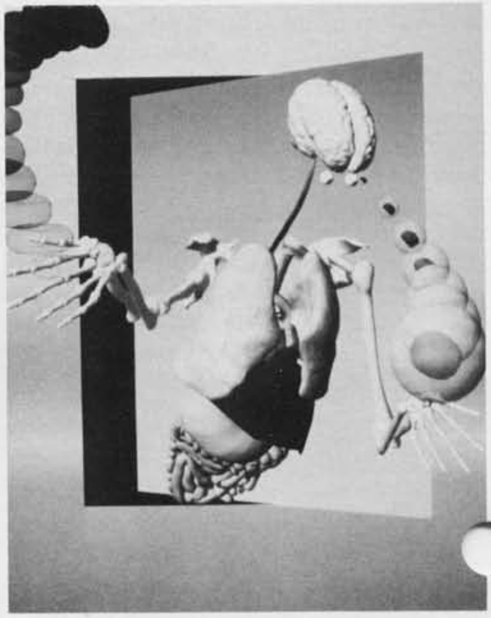
American Airlines
Apple Computer
The Arbor Inn
Arne's Fine Seafood
Bay Tower Room
Gwen Bell
Peter Benjamin, photographer
The Beverly Hills Hilton
Mr. & Mrs. Lawrence A. Bianchi
Bitstream, Inc.
The Boston Ballet Company
The Boston Computer Society
The Cambridge Center for Adult Education
The Charles Hotel
Continental Airlines
Phil Cooper, Palladian Software, Inc.
Debra Corbett, fine artist
Culinary Classics
Debra's Catering to Your Every Whim
The Cast of Dynasty
East Meets West
Face Life
Fifth Avenue Limousine Service
Debbie Germain, Piece-A-Cake
Gourmet Caterers, Inc.
GWV Travel, A division of The Interface Group
The Hampshire House
Hewlett Packard Company
Danny Hillis
Jameson and Thompson Framers
Javelin Software
Jonah's
Carol & Joe Levy
Lorimar Productions
Lotus Corporation
Lotus Development
Mr. & Mrs. James L. McKenney
Montanas
Natural Microsystems
NEC
New York Air
The Ocean Club
Nancy Philo Olsen, fine artist
Andrea Peters, fine artist
Hank Phillippi
Polymedia
Jerry Rabinowitz, photographer
Annie Roe-Hafer
Savenors Market
Sheraton Corp.
S.T. Dupont, Orfevres a Paris
The Tandy Corporation
Robert Tinney, fine artist
Tomy Corporation
Toshiba America
The Wang Center for the Performing Arts
Warners Bros. Television & the Cast of "Spenser for Hire"
Michael P. Wasserman Associates

We would like to remind all the contributors and all the guests that every bit of their generosity sharpened the leading edge of the world's only computer museum.

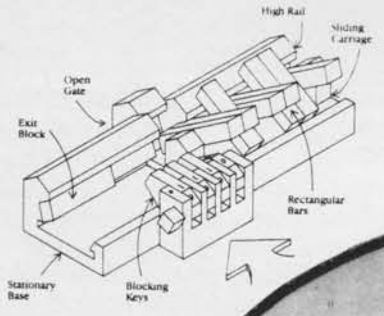
Computer Graphics Image Contest

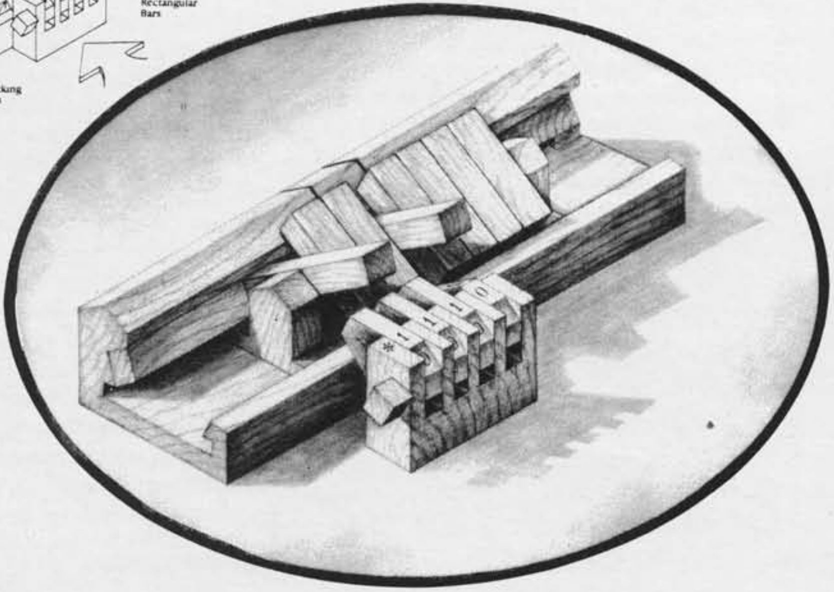
The Computer Museum and Raster Technologies Inc. are co-sponsoring The Second Annual International Computer Graphics Image Contest. The contest represents an international search for the most outstanding computer graphics image. Entries will be judged on both technical excellence and creative originality. As with last year's contest, the judges include the Museum's curator, Dr. Oliver Strimpel and members of the educational, technical and artistic communities: Dr. Richard Phillips, professor in the departments of Aerospace Engineering and Computer Science and Engineering at the University of Michigan, Dr. Andries van Dam, professor of the Computer Science Department, Brown University, Ms. Terry Blum, fine artist and coordinator of the computer graphics lab at the Fashion Institute of Technology and Mr. Robert P. Holton, publisher of *Computer Graphics World*.

Prizes range from $200 to $2000 and winning images will replace the 1985 winners on display in **The Computer and the Image** gallery at the Museum in September. Members are invited to submit entries and are encouraged to spread the word among friends and colleagues. Please contact Raster Technologies at (617) 692-7900 for further information and entry forms. Contest entries must be in 35mm slide format, and reach Raster Technologies by June 1 1986.



The Hexadecimal Puzzle





An Advanced Mathematical Puzzle With Sixteen Variations

The Computer Museum is offering you a limited opportunity to purchase The Hexadecimal Puzzle in an edition signed by the puzzle's inventor. The puzzle is offered to you at a cost of only $39.95 (members $35.95).

The Hexadecimal Puzzle is a binary switching sequence puzzle designed by William Keister, a pioneer in switching system theory and design at Bell Laboratories. The object is to remove the sliding carriage from the stationary base. This can be accomplished by switching each of the eight rectangular bars on the carriage from their initial position under the high rail to a position over the high rail. The switching action is hindered by a set of four blocking keys; to switch a given carriage bar, all bars to its left must have previously been switched to a pattern which matches the blocking key pattern for that bar.

Each of the four blocking keys can be adjusted by the player to a "0" or "1" position. Because of this, the blocking key pattern can be adjusted to 16 unique settings, forming sixteen unique puzzle sequences. Made of cherry wood, the Hexadecimal Puzzle is a handsome object as well as a challenging pastime.

Write The Computer Museum Store, or phone (617)542-0476.

Spring Program Series

Lecture Series Thursday Nights at 7pm

April 3

Robert McAndrews, President, The New England Commons
Wired Learning: The Future of Computer Networking in Higher Education

April 10

Dr. Peter Richter, Professor of Physics at the University of Bremen and Dr. Robert Devaney, Professor and Chairman of Mathematics, Boston University

Colors of Chaos
Background and explanation of the images in the exhibit (see below)

April 17

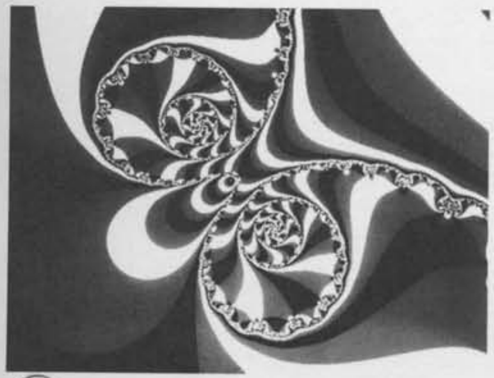
Seymour Papert, Professor, MIT, Learning Epistemology Group, Media Lab
Computers and Learning in Early Childhood

May 1

Lillian Schwartz, Computer Artist Pioneer, Bell Laboratories
The Computer as a Medium in the Arts

May 8
Film Night

"Forbidden Planet", 1956, 98 minutes, color.
A classic science fiction film, "Forbidden Planet" is the story of an interstellar expedition that discovers the lone survivors of an earlier voyage. Morbius (Walter Pigeon) and his daughter are the survivors found amidst the remnants of an incredible advanced civilization whose inhabitants mysteriously vanished centuries before.



April 10

Colors of Chaos

An exhibit of computer generated images showing the iteration of complex functions.

A vividly colored series of images created by Dr. Peter Richter and colleagues at The University of Bremen, West Germany, shows the Mandelbrot Set and several Julia Sets. The function iterated here is simply squaring the complex number. Another series, by Professor Robert Devaney of Boston University, shows iterations of sine and cosine. The richness and beauty of the patterns was entirely unpredicted before computer exploration became possible.

The exhibit opens on April 10 with a special reception for museum members starting at 6pm followed at 7pm by a lecture. Peter Richter and Robert Devaney will explain what the images mean and how to generate such images yourself.

Courtesy of Heinz-Otto Peitgen and Peter Richter

The End Bit

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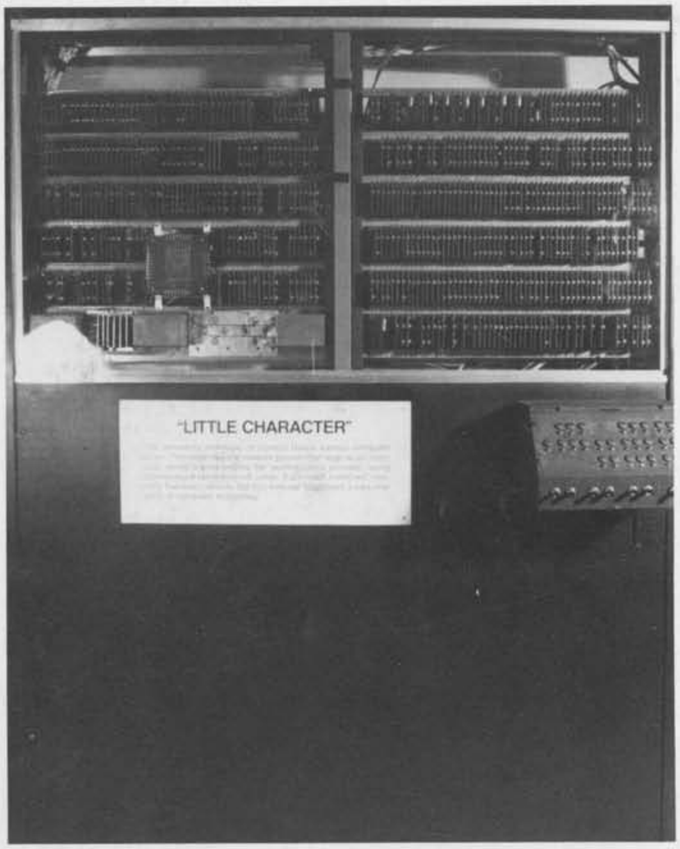

Little Character, by Control Data Corporation, 1959. The Little Character was a prototype computer developed to test the concept of modular circuit design at Control Data Corporation shortly after its incorporation in August 1957.

When he joined the young company in 1958, Seymour Cray tried to persuade president William Norris that there was a market for a low-cost, high-speed computer designed for scientific applications. Norris was sufficiently convinced to let Cray develop the Little Character. The machine used a small number of standard circuits made by loading transistors onto small circuit boards. These in turn were connected via a hand-wired backplane.

The Little Character vindicated Cray's modular design and Norris was convinced. The company then used the ideas embodied in the Little Character to build the Control Data 1604, a computer aimed at the low-priced scientific market.

On loan from Control Data Corporation, Minneapolis, Minnesota

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