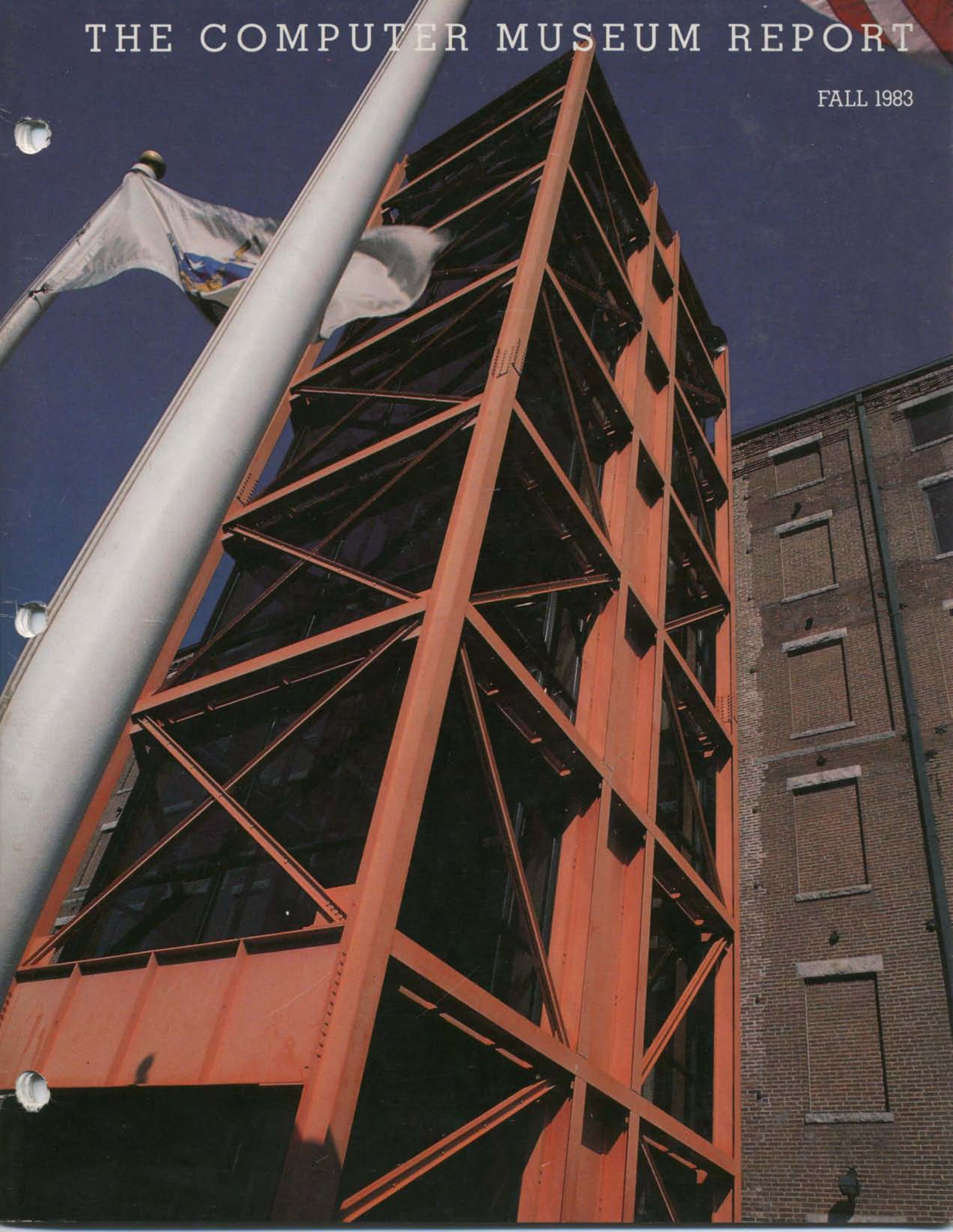
THE COMPUTER MUSEUM REPORT

FALL 1983



Contents

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David Bromfield pp. 9, 13, 15, and cover

Pictured against a crystal-clear sky is the glass-enclosed elevator that will be the entryway to The Computer Museum in its new location on Museum Wharf, Boston (see director's letter for more information on the move).

CBS, *The Thinking Machine* pp. 5

Shag Graetz pp. 6, 8, 10, 11, 12,

Steve Rosenthal pp. 1, 2

Carolyn Sweeney pp. 14, 15

THE COMPUTER MUSEUM

The Computer Museum is a non-profit, public, charitable foundation dedicated to preserving and exhibiting an industry-wide, broad-based collection of the history of information processing. Computer history is interpreted through exhibits, publications, videotapes, lectures, educational programs, and other programs. The Museum archives both artifacts and documentation and makes the materials available for scholarly use.

The Computer Museum is open to the public Sunday through Friday from 1:00 to 6:00 pm. There is no charge for admission. The Museum's lecture hall and reception facilities are available for rent on a prearranged basis. For information call 617-467-4443.

Museum membership is available to individuals and non-profit organizations for $25 annually and to businesses for $125 annually. Members receive the quarterly Report, invitations to all lectures and special programs, new posters, and a ten percent discount in the Museum store.

A Founders program is in effect during the initial two-year period of the Museum, until June 10, 1984. During this period individuals and non-profit organizations may become Founders for $250 and businesses and charitable Foundations may become Founders for $2500. Founders receive all benefits of membership and recognition for their important role in establishing the Museum.

THE COMPUTER MUSEUM REPORT

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The design and production of the Report is done by Benson and Clemons.

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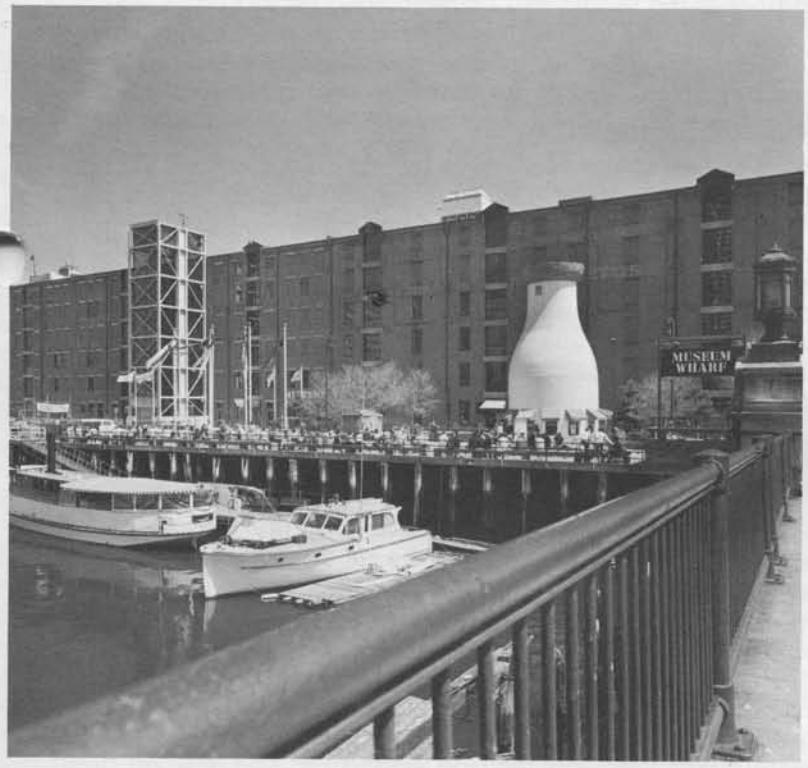
Next fall, The Computer Museum should be operational in downtown Boston at Museum Wharf, a six story condominium for two museums. The Museum will occupy floors five and six. Visitors will enter The Computer Museum via the majestic elevator pictured on the cover. The decision to move was made quickly, but with care.

Last summer, just after we had opened our doors as a public museum, Michael Spock, Director of Boston's Children's Museum and member of The Computer Museum Board, called me and asked, "Would you consider moving to Museum Wharf?"

I retorted, "You've got to be kidding, we just opened in Marlboro." But the seed had been planted.

During the last year, the most common questions from visitors and members were: "In the long run, where do you think the Museum should be?" "How long do you think the Museum will stay in Marlboro?" To be able to respond to these, we evaluated alternative locations that would be convenient to our public: people from around the world interested in computers. Proximity to the airport, convention hotels and local universities were critical factors. The stumbling block was money. Unless a special opportunity arose, relocating would cost tens of millions of dollars and take years of planning.



In January, Mike called again and asked if the Museum would consider moving to the top two floors of Museum Wharf. I knew we should take him seriously, but I questioned the suitability of the Wharf space. Having just installed a 9,000 pound section of ILLIAC IV, I asked, "What's the loading capacity of the floor?"

He replied, "One hundred pounds per square foot."

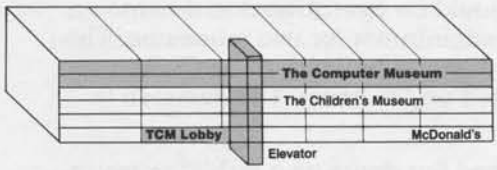
"That's double our present loading capacity," I said. "But, how can we get a 12 × 8 × 4 foot machine to the top floors?"

"No problem," said Spock, "You can drive a fire engine into one end of the elevator and out the other onto the floor."

The location fit the criteria. The site has a canal-front park with a view of downtown Boston. It is minutes from the airport, a short walk from South Station and the "redline" subway that stops near MIT and Harvard, and is convenient to convention hotels. Also, BOSCOM, a permanent international computer marketcenter opening in late 1984 on Commonwealth Pier, is within walking distance.

Exhibit coordinator Jamie Parker and I made an appointment to see the space. The Museum of Transportation had recently moved out leaving a bare shell equipped to hold another museum. The sprinkler system, heating system and public facilities were all up to code. And the structure itself, built as a wool warehouse, had large generic spaces into which exhibits could be set. The Computer Museum could occupy 60,000 square feet, six times more space than it has in Marlboro. While The Computer Museum's goals indicate an eventual need for several hundred thousand square feet, Museum Wharf provides the appropriate next step.

But we did not let ourselves get excited. The Museum didn't have any funds to purchase the property and Mike Spock and the Board of The Children's Museum needed to have a rapid decision. I talked about the issue with Ken Olsen, Chairman of our Board. He in turn took the issue to



the officers of Digital Equipment Corporation. The consensus was that if the building provided good value for the Museum, and if enough support would be forthcoming, then it was appropriate to make the move. Digital had been happy to provide an incubator for the Museum, and would be proud to have it move to proper museum quarters at the right time.

Two studies were undertaken to test whether we should purchase one half interest in Museum Wharf. Digital's real estate department determined the value to be received was very high. For a down payment of $1,200,000 and half interest in a $1,600,000 Industrial Revenue Bond (at 8.5% interest to 1999), The Computer Museum will own half of a 155,000 square-foot building equipped as a museum. This is a third of the cost that most museums have to pay for similar space in similar locations. Simultaneously, Robert J. Corcoran Associates undertook a feasibility study to determine whether $5 million could be raised for this project. After more than sixty interviews with industry leaders, they gave the project an unequivocable green light. The Board of Directors of The Computer Museum then agreed to undertake the necessary fundraising to enable this move.

Since then, the staffs of the two museums have met together and started to work on appropriate ways to share and cooperate as the owners of Museum Wharf.

The ground floor of the Wharf will be developed for public spaces. Both museums will have separate lobbies and separate museum shops, accessible to the public without entering the museums. MacDonalds has a long term lease on the bay on one end of the building, and in the summertime "The Milk Bottle" is open as a refreshment stand.

The Children's Museum occupies floors two through four and is accessible by several interior stairways. Unlike many children's museums, it is both collection based and hands-on. The Americana, Native American, and Japanese collections provide the basis for exhibits, study and teacher resource material. The centerpiece of the Japanese collection is a recreated 16th century silk merchant's house from Kyoto. Visitors take off their shoes, sit on tamamis and listen to an interpreter tell about life in the house. The collections and study areas are housed in special climate-controlled areas beyond the house. The curatorial staff of The Children's Museum will help us understand how best to use the Wharf building for exhibits and the interrelation of study, collections and exhibitions—an important concept for The Computer Museum to develop.

This move will bring the Museum to a new threshold in developing exhibits. The members, many who act as "curators," have helped us acquire and interpret the exhibits, resulting in a technical presentation. After an exhibit is up, they comment and criticize, and we make changes. Many visitors at Museum Wharf will be laymen, so our exhibits must be more accurate from the start and must be layered from a general to a technical level. Because member input has been so valuable, the exhibits will open for members only as a field test. If all goes well, next May you will be invited to Museum Wharf to review the first exhibition. And with all that has happened in this past year, I'm betting on it.

Gwen Bell
Director

Symposium

The Computer Museum sponsored two-day symposium in May on archiving issues in information processing history.

In only 35 years, the Information Revolution has produced more historical records on itself in more forms than those available about any previous scientific era.

Symposium attendees included archivists and others from The MITRE Corporation, Lawrence Livermore Laboratories, Travellers Insurance Company, the MIT Library and Museum, Elecitherian Mills Museum, Clark University, the Charles Babbage Institute, the Annals of the History of Computing, and the National Museum of Science and Technology, Canada.

"Criteria and taxonomies must be established for collections," said Helen Slotkin, archivist at MIT, "The first step is the general taxonomy of the field, such as that provided in Bell and Newell's *Computer Structures* and adopted by The Computer Museum. The second step is the decision of whether or not to save any particular document."

Slotkin emphasized that a "record" is a "record" independent of the field, and contemporary standard archival criteria for preservation may be used. But contemporary standards are different from those passed down from librarians in the days when everything could be saved, shelved and cataloged.

Gordon Bell and Jean Sammet, both authors of historical "trees," argued about the placement of limbs and branches and agreed that getting the tree planted was the significant point. A forest with a limited number of species for various major collecting areas would then give the overall picture.

The importance of different collections was also discussed. Arthur Norberg, director of the Charles Babbage Institute, described its focus on the early papers of the individuals who formed the industry, and hence the evolution of the information processing industry. Computer Museum archivists explained its collecting policy—the Museum starts with hardware and then collects the accompanying documentation. It was recognized that each institution would provide archives in keeping with its primary role. For example, universities and company archives would be expected to be primary sources for the papers on people and activities primarily associated with them.

Computer historian Paul Ceruzzi made the case that although we need to see documents of all kinds, the artifacts themselves are also valuable. A movie or a set of prints just does not provide the same understanding as the object itself, or even a few pieces of the object; and whenever those have survived they ought to be saved.

The symposium opened with a showing of videotapes and films of information processing, followed by a discussion. The films were grouped into three kinds: (1) "Vintage films" (at least 15 years old) that have been found and considered to be worth saving; (2) Contemporary documentaries made with a historic purpose in mind, which include the commissioned videotapes of The Computer Museum and the video-history program at MIT under the direction of Ithiel de Sola Pool and his assistant, Richard Solomon; (3) Videotaped presentations of lectures and conferences devoted to historic topics.

"What would we give for a film of Babbage and Ada Lovelace just chatting, not even saying anything of historical interest?"

Video archives create separate archival issues. Videotapes are easy to make and getting less expensive every day, yet they are time consuming to edit, expensive to preserve, and require special equipment to watch.

Martin Campbell-Kelly, a collector of vintage films who uses films in his classes at the University of Warwick, led off the discussion. He suggested that all films and video should be rated. This set the group into discussion.

Jean Sammet: "Outside from the caveat of cost (and I realize that is a big one), I think everything created on film ought to be kept. I want to see expression on people's faces. I suspect that everyone has watched a rocket launch and gotten a thrill from it. It's only a piece of machinery going up in the air. And so what? Fifty or a hundred years from now school children will watch them and think they are hysterical."

Helen Slotkin: "There were 1,024 rocket launches that were filmed. The national archivist has asked, do we have to keep all of them? There were 150 failures and everyone agrees to keep them."

Richard Solomon: "What would we give for a film of Babbage and Ada Lovelace just chatting, not even saying anything of historical interest?"

Gwen Bell: "We not only have to be concerned with what we save but also what we create."

Helen Slotkin: "An archivist is passive. Only gathers things. In creating records, you are saying there are holes and we will fill them. It is conscious and after-the-fact."

Gordon Bell: "Guidelines are needed for making films, because the Museum commissioned two films of decommissioning of machines; one is great and the other is awful."

Ithiel de Sola Pool: "The important thing is the groups of people and their relationships and how this comes across on videotape. Factual information can be better transferred in other ways."

Helen Slotkin: "Unless you know who the user will be, you can't make the decision about what to save. If you decide to film a conference, it could be used five different ways, and in each case it would be done differently."

Gordon Bell: "Let's only deal with the producer/storer problem, not the consumer problem. Nice to have the Los Alamos tapes and the Museum lecture tapes—in the first case the people were in a group and defending their turf and in the second they were on their own—the star. We need a set of rules of how to cut at the source."

Barbara Costello (Lawrence Livermore Laboratories): "Accuracy in videotapes is relatively difficult; not the same control as books; especially on the made tapes."

Gwen Bell: "At present, for the produced tapes, there is no reviewing system as there is for an article or book. They don't have the same kind of close scrutiny."

The Computer Museum's Video Archives:

Jean Sammet: "The script for the ENIAC tape could have been reviewed."

Ithiel de Sola Pool: "Yes, but my point is that Arthur Burks says that better on paper, and the interesting part is the film."

Gwen Bell: "But we commissioned the voice-over to help people understand the film."

Martin Campbell-Kelly: "I have the non-voice film and now I know that I want the voice-over version. Burks says exactly what people need to know. I bought the Fortran tape from the HOPL set because I thought it would be useful for teaching, but it was a disaster."

Jean Sammet: "What are you telling me? We shouldn't have made it? Shouldn't be selling it?"

Mike Williams (University of Calgary): "Looking at a cannibalized piece of the ENIAC, like the one at the Museum, doesn't do much for me. Why not just videotape everything and throw the junk out?"

Jean Sammet: "Wait a minute. There's a big difference between three dimensions and two. You want to see a picture of The Spirit of St. Louis and the airplane and get a feel for just what Lindberg had to contend with."

Martin Campbell-Kelly: "I travelled from England to see these pieces of junk and they do something for me. You'll eat those words when you see the Mark I at Harvard."

"A picture is worth a thousand words."

A gigantic computer flashes on the screen. The camera zooms in and we see a video display screen blinking "Hello, Mr. Murrow."

We're watching the Whirlwind starring on a 1952 segment of "See It Now." This film clip is not only worth a thousand words but 150,000 watts: the power necessary to turn on Whirlwind, which had less computing power than an Apple II. Old films can let visitors and scholars see historic machines in action—see what they were like and what it might have been like to program or work on one of them.

The video archives parallel the artifact collection—one often leads to the other. Usually the acquisition of a machine leads to finding film footage, but occasionally it happens in reverse.

The films and videotapes fall into three major categories: vintage films; historical documentaries; and lecture or conference videotapes.

Vintage Films

The Museum's Collection of vintage films, films made about contemporary computing to reach audiences of their time, is expanding slowly with the help of Museum members and other interested collectors. Through a lead from a Stanford Computer Science alumnus about a very good early film on timesharing, the Museum acquired *Ellis D. Kroptechev and ZEUS, his Marvelous Timesharing System.*

Two other films, *Machines That Think* (1922) and *Introduction to Punched Card Accounting* (1928) were added to the film and video archives on the suggestion of Martin Campbell-Kelly, an avid film collector and Professor of Computer Science, University of Warwick.

To date, the collection has only contemporary documentaries. The Museum would like to branch out and start a collection of vintage entertainment films featuring the computer as a central character. *2001, Deskset,* and *Metropolis* are some examples. We would like to know your favorites as we start to build this collection.

Historical Documentaries

Historical documentaries are films made to preserve history. When one-of-a-kind machines are being retired, the Museum urges that a film be made of the installation. A 15-minute documentary was made by Brigham Young University of the last Stretch (IBM 7030) in operation, at our request. Stretch, in its later years, was not the same as Stretch in the early sixties when it was the centerpiece of Los Alamos. The film, although important, doesn't have the snap of a film made for a contemporary purpose. Yet historical documentaries are essential to make when nothing else exists.

The Museum has also shot over two hours of raw footage of Harold Cohen making his art, and made one documentary that explains the 1981 version of his program. We will supplement that with the footage showing the more recent evolution of his computer art.

Lecture and Conference Videotapes

The Museum's lecture videotapes and assorted History of Computing Conference videotapes represent over two-thirds of the Museum's film and video collection. These videotapes of significant contributors to the development of information processing technology serve as a primary data source for scholars and students. The Museum receives requests from across the country for copies of specific lecture tapes. Included are first-hand opinions from Konrad Zuse, who believed that with the development of the stored program "the devil entered the machine," and vivid reminiscences of Grace Hopper, who described the pressures of working during WWII on the Mark I. These tapes provide direct accounts of crucial developments in computing technology and indirectly convey the environment and atmosphere of the projects. Each lecture at the Museum is videotaped for the archives. The History of Programming Languages, 1978 (HOPL), and International Research Center, 1976 (IRC) Conference tapes were gifts from private donors.

Film and Video Archives

Once received by the Museum staff, the film or videotape is carefully indexed and then sent to a professional lab to be copied onto videotape. The masters of the films and videotapes are then stored in a climate controlled room monitored by a professional staff. Videotapes are run once a year to maintain their quality.

The copies of the original films and videotapes are held in the film and video archives for viewing by staff and Museum members.

The Film and Video Collections

Vintage Films

Apollo Guidance Computer, (silent film) Apollo Instrumentation Laboratory at MIT, circa 1968, 20 minutes. Gift of Charles Stark Draper Laboratory.

EDSAC, Cambridge University Mathematics Laboratory, 1951, 10 minutes. Gift of Maurice Wilkes.

ENIAC: Newsreel footage with narration by Professor Arthur Burks, The Moore School and The Computer Museum, 1946, 30 minutes. Gift of Arthur Burks.

In Your Defense: SAGE, Western Electric and the U.S. Air Force, 1961, 25 minutes. Gift of MITRE Corporation.

Introduction to Punched Card Accounting, circa 1928.

LINC With Tomorrow, National Public Television, circa 1965. Gift of Digital Equipment Corporation.

Machines That Think, Stoll Theatres, 1922.

Making Electrons Count, MIT and the Office of Naval Research, 1953, 25 minutes. Gift of MIT.

MANIAC, Los Alamos Scientific Laboratory, circa 1961, 20 minutes. Gift of Los Alamos Scientific Laboratory.

MIT Lincoln Laboratory TX-0, MIT, 1959, 10 minutes. Gift of MIT.

See It Now: The WHIRLWIND, CBS TV, 1952, 6 minutes.

Sketchpad: MIT Lincoln Laboratory TX-2, MIT, 1960, 12 minutes. Gift of MIT.

The Powers-Samas Film, (silent) British Biological Records Center, circa 1960, [illegible] minutes.

Tomorrow: The Thinking Machine, CBS TV, 1961, 60 minutes. Gift of MIT.

Ellis D. Kroptechev and Zeus, his Marvelous Time Sharing System, Stanford University, circa 1965, 15 minutes. Gift of Stanford University Computer Science Department.

Historical Documentaries

A CAM (Computer-Aided-Manufacturing) Update, Automatix, 1980, 40 minutes. Gift of Automatix.

Art by Computer: Museum Murals by Harold Cohen, The Computer Museum, 1980, 8 minutes.

Adaptive Control Devices, Case Western Reserve University, Instructional Television Network, 1978, 14 minutes. Gift of Jim Rogers.

History of Computing in Business, GTE's Communication and Training Center, 11 minutes. Gift of IDG.

Invention of the First Electrical Digital Computer, Bell Labs, 15 minutes. Gift of Bell Labs.

Powers of Ten, Pyramid, 10 minutes, 1978.

STRETCH: The Technological Link between Yesterday and Tomorrow, Brigham Young University and The Computer Museum, 1981, 15 minutes.

Museum Lectures

Amdahl, Gene, **From WISC to TRILOGY,** 1983.

Atanasoff, John Vincent, **The Forces That Led to the Design of the Atanasoff-Berry Computer,** 1980.

Brainerd, John, **ENIAC,** 1981.

Burks, Arthur, **The Origin of the Stored Program,** 1982.

Wes Clark, **LINC,** 1981.

Cohen, Harold, **How I Produce Computer Generated Art,** 1980.

Edwards, Dai, **Early Manchester Computers,** 1981.

Flowers, Tom H., **Design and Use of Colossus: WWII Code-Breaking Machine,** 1981.

Forrester, Jay, **Whirlwind,** 1980.

Grosch, Herbert, **The Watson Scientific Laboratory, 1945–1950,** 1982.

Hopper, Grace, **Howard Aiken and the Harvard Mark I,** 1983.

Huskey, Harry, **From Pilot ACE to the G-15,** 1982.

Lehmer, D.H., **History of the Sieve Machines,** 1982.

Hogan, Les, **The Origin, Evolution and Future of the Semiconductor Industry,** 1983.

Stibitz, George, **Design of the Bell Labs Relay Computers,** 1980.

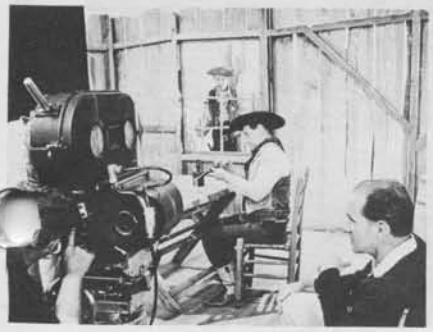
Wilkes, Maurice, **EDSAC,** 1979.

Wilkinson, James, **The Pilot ACE,** 1981.

Zuse, Konrad, **Z1, Z2 and Z3, 1936–1947,** 1981.

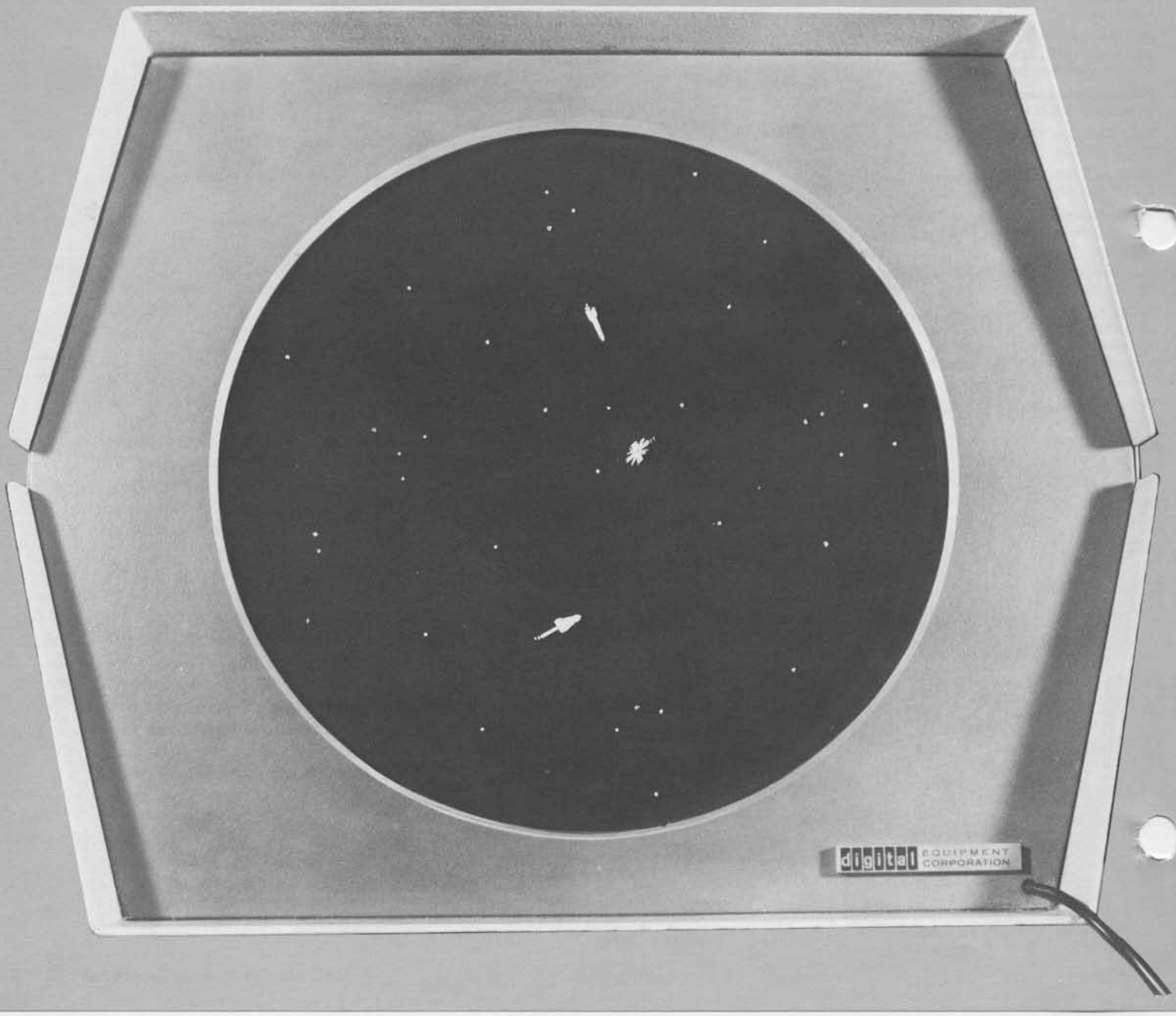
History of Programming Languages (HOPL) Conference, Los Angeles, California, June 10, 1978. 23 videotapes. Gift of Association for Computing Machinery.

International Research Conference (IRC) on the History of Computing in the Twentieth Century, Los Alamos, New Mexico, June 10–15, 1976. 33 videotapes. Gift of Bill Luebbert.



The last segment of Tomorrow: The Thinking Machine, *a 1961 TV program produced by CBS for MIT's one hundredth birthday, features a computer-written Western. Harrison (Dit) Morse wrote the program on the TX-0 (with its 32K bits of core memory). Doug Ross (upper right) explains the logical choices the machine could make about the placement of the robber and the sheriff, the gun, the table, the window, the door, the whiskey bottle, etc. Actor Jack Gilford plays the role of the robber, cleaning his gun while the sheriff looks on. Three versions are produced on the film, including one in which the computer program got stuck in a loop.*

A question to the readers: Does this program and film qualify as the first artificial intelligence program written to produce a play?


digital EQUIPMENT CORPORATION

The Origin of Spacewar

J. M. Graetz

1. BEFORE SPACEWAR!

The Lensman, The Skylark, and the Hingham Institute

It's Kimball Kinnison's fault. And Dick Seaton's. Without the Gray Lensman and the **Skylark of Space** there would be nothing to write about. So most of the blame falls on E. E. Smith, but the Toho Film Studios and the American Research and Development Corp. have something to answer for as well. If Doc Smith had been content designing doughnuts, if American-International Pictures had stuck to beach blanket flicks, if (most of all) General Doriot hadn't waved money in front of Ken Olsen in 1957, the world might yet be free of **Spacewar!**

It all came together in 1961 at the Hingham Institute, a barely habitable tenement on Hingham Street in Cambridge, MA. Three Institute Fellows were involved: Wayne Wiitanen, mathematician, early music buff, and mountain climber; J. Martin Graetz (which is me), man of no fixed talent who tended to act superior because he was already a Published Author; and Stephen R. (Slug) Russell, specialist in steam trains, trivia, and artificial intelligence. We were all about 25 (the more or less to be the same).

At the time, we were crashing and banging our way through the "Skylark" and "Lensman" novels of Edward E. Smith, PhD, a cereal chemist who wrote with the grace and refinement of a pneumatic drill.

In a pinch, which is where they usually were, our heroes could be counted on to come up with a complete scientific theory, invent the technology to implement it, build the tools to implement the technology, and produce the (usually) weapons to blow away the baddies, all while being chased in their spaceship hither and thither throughout the trackless wastes of the galaxy (he wrote like that) by assorted Fenachrone, Boskonians, and the World Steel Corporation.

In breaks between books, we would be off to one of Boston's seedier cinemas to view the latest trash from Toho. These movies depended for their effects on high quality modelwork, oceans of rays, beams, explosions and general brouhaha, and the determined avoidance of plot, character, or significance. They were the movie equivalent of **The Skylark of Space.**

If that's the case, we asked ourselves, why doesn't anyone make **Skylark** movies? Hearing no reply (our innocence of current film technology, economics, and copyright laws was enormous), we often passed the time in the Hingham Street common room in deep wishful thought, inventing special effects and sequences for a grand series of space epics that would never see a sound stage. Nonetheless, these books, movies, and bull-sessions established the mind-set that eventually led to **Spacewar!**

When Computers Were Gods

In early 1961 Wayne, Slug, and I, by no coincidence, were all working at Harvard University's Littauer Statistical Laboratory. A large part of our jobs was to run statistics computations on an IBM 704.

To a generation whose concept of a computer is founded on the Z80 chip, it may be hard to visualize a 704 or to comprehend the place it held in the public imagination. It was a collection of mysterious hulking gray cabinets approachable only through the intercession of The Operator.

Everything about the 704, from the inscrutable main frame to the glowing tubes in the glass-walled core memory case, proclaimed that this was a Very Complicated System operated only by Specially Trained Personnel, among whom programmers and other ordinary mortals were not numbered. In short, a computer was something that you simply did not sit down and fool around with.

A Stone's Throw From Olympus

In the summer of 1961 I went to work for Professor Jack B. Dennis, who was then the proprietor of the TX-O, a machine that to me was only slightly less legendary than its ancestor, Whirlwind. The TX-O was transistorized, and while solid-state computers were beginning to appear on the market, the "Tixo" was the original. Even in 1961 it was acknowledged to be a historically important research facility; many of the programs developed on the TX-O, such as Jack Dennis's MACRO Assembler and Thomas Stockham's FLIT debugging program, were the first of their kind. So the chance to work on this computer was in many ways a rite of passage; it meant that I had joined the ranks of the Real Programmers.

While hardly your average populist Apple, the TX-O was definitely a step away from the Computer-As-Apollo. Instead of being sealed into its own special chapel, it sat at one end of a typical large, messy MIT research space. With its racks of exposed circuitry, power supplies and meters, and its long, low L-shaped console, the TX-O looked for all the world like the control room of a suburban pumping station. And the thing of it was, you were expected to **run it yourself.**

The TX-O's input and output medium was a Flexowriter: an all-in-one keyboard, printer, paper-tape reader and punch, that worked like a mule and had a personality to match. There was also a "high-speed" paper tape reader, a Grand Prix whiz that could read programs into memory almost as fast as the cassette-tape reader on a TRS-80.

And the TX-O had a scope. Console-mounted, programmable CRTs were not unheard of at that time but they were generally slow, inflexible, and awkward to program. The TX-O scope, on the other hand, was easy to use; you could generate a useful display with fewer than a dozen instructions. And if that weren't enough, there was a magic wand: the light pen.

That was the TX-O: the world's first on-line computer, and the training ground for the designers and programmers of later generations of hands-on machines. The first computer bums—hackers—were the products of this training; without it, and them, there would have been no **Spacewar!**

Tixo's People

The users of the TX-O were a melange of students, staff researchers and professors with not much in common other than their need for large amounts of largely unstructured computer time. The feel of the place, however, was established by the hackers—mostly students, but including a professor or two—whose lives seemed to be organized in 18-bit strings.

Out of this cloud of computer bums emerged the group that brought **Spacewar!** to the silver (well, light gray) screen: Dan Edwards (AI Group), LISP specialist; Alan Kotok (TX-O staff), who wrote the MIDAS Debugger; Robert A. Saunders (TX-O staff), who wrote

MIDAS, the successor to MACRO; Peter Samson (AI Group), who made the Tixo and PDP-1 play Bach, and Steve Russell and I.

"You Mean That's All It Does?"

When computers were still marvels, people would flock to watch them at work whenever the opportunity arose. They were usually disappointed. Whirring tapes and clattering card readers can hold one's interest only so long. They just did the same dull thing over and over.

On the other hand, something is always happening on a TV screen, which is why people stare at them for hours. On MIT's annual Open House day, for example, people came to stare for hours at Whirlwind's CRT screen. What did they stare at? Bouncing Ball.

Bouncing Ball may be the very first computer-CRT demonstration program. It didn't do much: a dot appeared at the top of the screen, fell to the bottom and bounced (with a "thok" from the console speaker). It bounced off the sides and floor of the displayed box, gradually losing momentum until it hit the floor and rolled off the screen through a hole in the bottom line. And that's all. Pong was not even an idea in 1960. (*Note: Well, maybe not Pong, but something very much like it. Watch these pages.* —DHA)

The TX-O's counterpart to Bouncing Ball was the Mouse in the Maze, written by Douglas T. Ross and John E. Ward. Essentially, it was a short cartoon; a stylized mouse searched through a rectangular maze until it found a piece of cheese which it then ate, leaving a few crumbs. You constructed the maze and placed the cheese (or cheeses—you could have more than one) with the light pen. A variation replaced the cheese with a martini; after drinking the first one the mouse would stagger to the next.

Besides the Mouse, the TX-O also had HAX, which displayed changing patterns according to the settings of two console switch registers. Well-chosen settings could produce interesting shapes or arrangements of dots, sometimes accompanied by amusing sounds from the console speaker. The console speaker is a phenomenon whose day seems to have passed. (More than just a plaything, for the experienced operator the speaker was a valuable guide to the condition of a running program.)

Finally, there was the inevitable Tic-Tac-Toe, with the user playing the computer. The TX-O version used the Flexowriter rather than the scope. (The game is so simple to analyze that there was even a version for the off-line Flexo.)

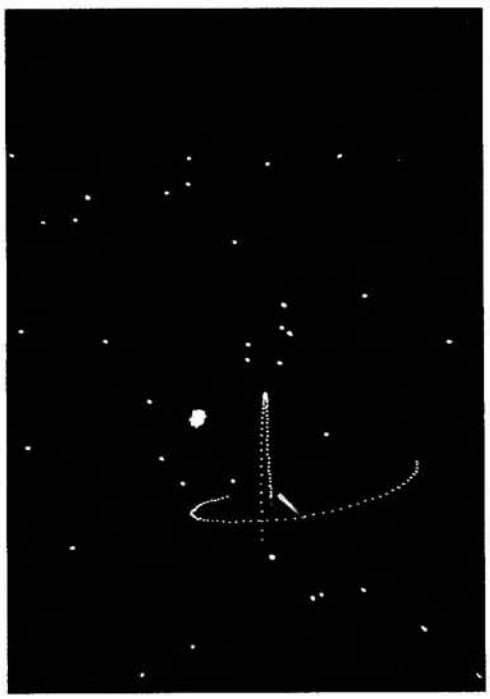
These four programs pointed the way. Bouncing Ball was a pure demonstration: you pushed the button, and it did all the rest. The mouse was more fun, because you could make it different every time. HAX was a real toy; you could play with it while it was running and make it change on the fly. And Tic-Tac-Toe was an actual game, however simpleminded. The ingredients were there; we just needed an idea.

The World's First Toy Computer

For all its homeliness, the TX-O was still very much a god. It took up lots of space, it had to be carefully tended, it took special procedures to start it up and shut it down, and it cost a lot of money to build.

All this changed in the fall of 1961, when the first production-model PDP-1 was installed in the "Kluge Room" next door to the TX-O. It had been anticipated for months; an early brochure announcing the machine (as well as a couple of noshows called the PDP-2 and PDP-3, in case you were wondering about that) had been circulating in the area for a while. It was clear that the PDP-1 had TX-O genes; the hackers would be right at home.

The -1 would be faster than the Tixo, more compact and available. It was the first computer that did not require one to have an E.E. degree and the patience of Buddha to start it up in the morning; you could turn it on anytime by flipping one switch, and when you were finished, you could turn it off. We had never seen anything like that before.



II. SPACEWAR! BEGUN

The Hingham Institute Study Group On Space Warfare

Long before the PDP-1 was up and running, Wayne, Slug and I had formed an ad-hoc committee on what to do with the Type 30 Precision CRT Display which was scheduled to be installed a couple of months after the computer itself. It was clear from the start that while the Ball and Mouse and HAX were clever and amusing, they really weren't very good as demonstration programs. Zooming across the galaxy with our Bergenholm Intertialess Drive, the Hingham Institute Study Group on Space Warfare devised its Theory of Computer Toys. A good demonstration program ought to satisfy three criteria:

1) It should demonstrate, that is, it should show off as many of the computer's resources as possible, and tax those resources to the limit.
2) Within a consistent framework, it should be interesting, which means that every run should be different.
3) It should involve the onlooker in a pleasurable and active way—in short, it should be a game.

With the Fenachrone hot on our ion track, Wayne said, "Look, you need action and you need some kind of skill level. It should be a game where you have to control things moving around on the scope, like, oh, spaceships. Something like an explorer game, or a race or contest . . . a flight, maybe?"

"SPACEWAR!" shouted Slug and I, as the last force screen flared into the violet and went down.

The basic rules developed quickly. There would be at least two spaceships, each controlled by a set of console switches ("Gee, it would be neat to have a joystick or something like that . . ."). The ships would have a supply of rocket fuel and some sort of weapon; a ray or a beam, possibly a missile. For really hopeless situations, a panic button would be nice . . . hmmm . . . aha! Hyperspace! (What else, after all, is there?) And that, pretty much, was that.

The Hackers Meet SPACEWAR!

By the end of summer, 1961, Steve Russell had returned to the Artificial Intelligence Group (he'd worked there before Littauer); consequently, whatever ideas the Study Group came up with were soon circulating among the hackers. **Spacewar!** was an appealing, simple concept, and the hackers

Gleefully playing **Spacewar!** *at a spring Bits and Bites talk are (left to right) Alan Kotok, Steve Russell and Shag Graetz.* **Spacewar!**, *the first video game and one of the Museum's software artifacts, was designed for a PDP1 by Graetz, Russell and Wayne Wittenan in 1961.*

were the appealingly simple people to bring it to life. First, however, there was the small matter of software.

The PDP-1 was a no-frills machine at the beginning; except for a few diagnostic and utility routines, there was no program library. In a way this suited the hackers just fine; here was a chance both to improve on TX-O software and to write new stuff that couldn't have been done before. First, and fairly quickly, MACRO and FLIT were translated from TXish to PDPese, FLIT becoming the first in a continuing line of DDT on-line debugging programs, Steve Piner PDP-1 wrote a text display and editing program called Expensive Typewriter.

With the software taken care of we could write real programs, which is to say toys. Bouncing Ball was successfully converted to PDP-1 use, but HAX for some reason, was not. But no one really missed it, because we had a brand-new toy invented by Professor Marvin Minsky. The program displayed three dots which proceeded to "interact," weaving various patterns on the scope face. As with HAX, the initializing constants were set in the console switches. Among the patterns were geometric displays, Lissajous-like figures, and "fireworks." Minsky's program title was something like "Tri-Pos: Three-Position Display" but from the beginning we never called it anything but The Minskytron. ("tron" was the In suffix of the early 1960s.)

First Steps

By the end of 1961, all the elements were in place, a brand new, available computer, a cloud of hackers, tolerant when not actively implicated employers, and an exciting idea. Slug Russell was getting the heat from everyone to "do something" about **Spacewar!** (I was in a different department at MIT by this time and Wayne, alas, was one of those unlucky Army Reservists called to active duty during the Berlin Wall panic in October. He never got to participate in developing his own idea.)

Russell, never one to "do something" when there was an alternative, begged off for one reason or another. One of the excuses for not doing it, Slug remembers, was "Oh, we don't know how to write a sine-cosine routine . . ." Then Alan Kotok came back from a trip all the way to Maynard (DEC headquarters) with paper tapes saying "All right, Russell, here's a sine-cosine routine; now what's your excuse?" "Well," says Slug, "I looked around and I didn't find an excuse, so I had to settle down and do some figuring."

With the heavy mathematics in hand, Slug produced the first object-in-motion program in January 1962. This was nothing more than a dot which could accelerate and change direction under switch control. Even without a hardware multiply-divide capability (on the early PDP-1s, anything stiffer than integer addition and subtraction had to be done by subroutine) the computer was clearly not being pushed.

From dot to rocket ship was a surprisingly easy step. "I realized" Slug says, "that I didn't have to worry about the speed of the sine-cosine routine, because there were only two angles involved in each frame—one for each ship. Then the idea of rotating the grid came out." The ship outlines were represented as a series of direction codes starting from the nose of the ship; when the ship was vertical and tail-down, each code digit pointed to one of the five possible adjacent dots that could be displayed next. To display the ship at an angle, Russell calculated the appropriate sine and cosine and added them to the original direction code constants, in effect rotating the entire grid. With this method, the ship's angle had to be calculated only once in each display frame. The outline codes were kept in a table so that different shapes could be tried out at will, but this meant that the table had to be searched every frame to generate the outline. As the game developed, this arrangement proved to be a sticking point which, as we shall see, was neatly solved by Dan Edwards.

By February, the first game was operating. It was a barebones model; just the two ships, a supply of fuel, and a store of "torpedoes"—points of light fired from the nose of the ship. Once launched, a torpedo was a ballistic missile, zooming along until it either hit something (more precisely, until it got within a minimum distance of a ship or another torpedo) or its "time fuse" caused it to self-destruct.

The classic needle and wedge ship outlines and the opposite-quadrant starting positions were established at this stage, as shown in Figure 1. Acceleration was realistic; it took time to get off the mark, and to slow down you had to reverse the ship and blast in the other direction; the rocket exhaust was a flickering "fiery tail."

Rotation, on the other hand, was

by something we called "gyros"—a sort of flywheel effect invented to avoid consideration of messy things like moments of inertia. I guess they were really rotational Bergenholms.

It was apparent almost immediately that the featureless background was a liability. It was hard to gauge relative motion; you couldn't tell if the ships were drifting apart or together when they were moving slowly. What we needed, obviously, were some stars. Russell wrote in a random display of dots and the quality of play improved. The only thing left, we thought, was hyperspace, and that was on the way. In fact, we'd just begun.

III. SPACEWAR! COMPLETE

Please keep in mind that what follows did not happen in a neat first-one-thing-and-then-the-next progression, but rather all at once in a period of about six weeks. When hackers are aroused, anything that can happen will.

The Control Boxes

Spacewar! worked perfectly well from the test word switches on the console, except that the CRT was off to one side, so one player had a visual advantage. More to the point, with two excitable space warriors, jammed into a space meant for one reasonably calm operator, damage to the equipment was a constant threat. At the very least, a jittery player could miss the torpedo switch and hit the start lever, obliterating the universe in one big anti-bang. A separate control device was obviously necessary, but joysticks (our original idea) were not readily available in 1962. So Alan Kotok and Robert A. Saunders, who just happened to be members of the Tech Model Railroad Club, trundled off to the TMRC room, scrabbled around the layout for a while to find odd bits of wood, wire, bakelite, and switchboard hardware, and when the hammering and sawing and soldering had ceased, there on the CRT table were the first **Spacewar!** control boxes (Figure 2. These boxes have long since disappeared, but the sketch is a reasonably accurate reconstruction).

The box is wood with a Bakelite top. The two switches are double-throw; the button is a silent momentary switch. Their functions are as follows:

a. Rotation control. It is pushed to the left to rotate the ship counter-clockwise, to the right to rotate clockwise.

b. A two-function control. Pulled back, it is the rocket accelerator; the rocket continues to blast as long as the switch is thrown. Pushed forward, the switch is the hyperspace control, as described below.

c. The torpedo button. It had to be silent so that your opponent could not tell when you were trying to fire. (There was a fixed delay between shots "to allow the torp tubes to cool" and fire was not automatic; you had to keep pushing the button to get off a missile.)

With the control boxes players could sit comfortably apart, each with a clear view of the screen. That, plus the carefully designed layout of the controls, improved one's playing skills considerably, making the game even more fun.

The Stars of the Heavens

One of the forces driving the dedicated hacker is the quest for elegance. It is not sufficient to write programs that work. They must also be "elegant," either in code or in function—both, if possible. An elegant program does its job as fast as possible, or is as compact as possible, or is as clever as possible in taking advantage of the particular features of the machine in which it runs, and (finally) produces its results in an esthetically pleasing form without compromising either the results or operation of the other programs associated with it. "Peter Samson," recalls Russell, "was offended by my random stars." In other words, while a background of miscellaneous points of light might be all very well for some run-down jerkwater space fleet, it just wouldn't do for the Galactic Patrol. So Peter Samson sat down and wrote "Expensive Planetarium."

Using data from *The American Ephemeris and Nautical Almanac*, Samson encoded the entire night sky (down to just above fifth magnitude) between 22½ degrees N and 22½ degrees S, thus including most of the familiar constellations. The display can remain fixed or move gradually from right to left, ultimately displaying the entire cylinder of stars. The elegance does not stop there. By firing each displayed point the appropriate number of times, Samson was able to produce a display that showed the stars at something close to their actual relative brightness. An attractive demonstration program in its own right, E.P. was "duly admired and inhaled into **Spacewar!**"

The Heavy Star

Up to this point, **Spacewar!** was heavily biased towards motor skills and fast reflexes, with strategy counting for very little. Games tended to become nothing more than wild shoot-outs, which was exciting but ultimately unrewarding. Some sort of equalizer was called for.

Russell: "Dan Edwards was offended by the plain spaceships, and felt that gravity should be introduced. I pleaded innocence of numerical analysis and other things"—in other words, here's the whitewash brush and there's a section of fence—"so Dan put in the gravity calculations."

The star blazed forth from the center of the screen, its flashing rays a clear warning that it was not to be trifled with. Its gravity well encompassed all space; no matter where you were, if you did not move you would be drawn into the sun and destroyed. (As a gesture of good will towards less skillful or beginning players, a switch option turned annihilation into a sort of hyperspatial translation to the "anti-point," i.e., the four corners of the screen.)

The star did two things. It introduced a player-independent element that the game needed; when speeds were high and space was filled with missiles, it was often sheer luck that kept one from crashing into the star. It also brought the other elements of the game into focus by demanding strategy. In the presence of gravity both ships were affected by something beyond their control, but which a skillful player could use to advantage.

The first result of this new attention to strategy was the opening move

in Figure 3, which was quickly dubbed the "CBS opening" because of its eye-like shape. It took a while to learn this maneuver but it soon became the standard opening among experienced players, as it generally produced the most exciting games.

The addition of gravity pushed **Spacewar!** over the edge of flicker-free display. To get back under the limit, Dan Edwards devised an elegant fiddle to speed up the outline display routine.

In Russell's original program, the outline tables were examined and interpreted in every display frame, an essentially redundant operation. Edwards replaced this procedure with an outline "compiler," which examined the tables at the start of a game and compiled a short program to generate the outline for each ship. This dramatically reduced calculation time, restoring the steady display and making room for the last of the original bells and whistles.

Hyperspace

While all this was going on, I was in my secret hideaway (then known as the Electronic Systems Lab) working on the ultimate panic button; hyperspace. The idea was that when everything else failed you could jump into the fourth dimension and disappear. This would introduce an element of something very like magic into an otherwise rational universe, the use of hyperspace had to be hedged in some way. Our ultimate goal was a feature that, while useful, was not entirely reliable. The machinery, we said, would be "the Mark One Hyperfield Generators . . . hadn't done a thorough job of testing . . . rushed them to the fleet"* and so on. They'd be good for one or two shots, but would deteriorate rapidly after that. They might not work at all ("It's not my fault, Chewie!") or if they did, your chances of coming back out intact were rather less than even. Slug: "It was something you could use, but not something you wanted to use."*

The original hyperspace was not that elegant. "MKI unreliability" boiled down to this: you had exactly three jumps. In each jump your ship's co-ordinates were scrambled so that you never knew where you would reappear—it could be in the middle of the sun. You were gone for a discernible period of time, which gave your opponent a bit of a breather, but you came back with your original velocity and direction intact. To jump, you pushed the blast lever forward.

Hyperspace had one cute feature (well, I thought it was cute). Do you remember the Minskytron? One of its displays looked very much like a classical Bohr atom, which in those days was an overworked metaphor for anything to do with space and science-fiction. Reasoning that a ship entering hyperspace would cause a local distortion of space-time resulting in a warp-induced photonicstress emission (see how easy this is?), I made the disappearing ship leave behind a short Minskytron signature (Figure 4).

Crocks and Loose Ends

In retrospect, it is remarkable that the original **Spacewar!** managed to include so many features, given the limitations of our PDP-1: 4K words (about 9K bytes) of memory, an instruction cycle time of five microseconds, and a subroutine multiply-divide. It's hardly surprising, then, that we had to let a few unsatisfactory (all right, inelegant) bits go by.

The most irritating of these (and the first to be improved in later versions) was the appropriately-named Crock Explosion. Something dramatic obviously had to happen when a ship was destroyed, but we were dealing with a plain dot-matrix screen. The original control program produced a random-dot burst confined within a small square whose outlines were all too discernible (Figure 5).

This explosion was intended merely as a place-holder until something more plausible could be worked out, but after all the other features had been "inhaled," there wasn't room or time for a fancier calculation.

Similarly, the torpedoes were not quite consistent with the **Spacewar!** universe after the heavy star was in place. The gravity calculations for two ships was as much as the program could handle; there was no time to include half a dozen missiles as well. So the torpedoes were unaffected by the star, with the odd result that you could shoot right through it and hit something on the other side (If you weren't careful getting round the Star, it could be you.). We made the usual excuses . . . mumblemumble photon bombs mumblemumble . . . but no one really cared.

The heavy star itself was not entirely Newtonian. The common tactic of plunging down the gravity well to gain momentum by whipping around the sun (Figure 6) gave you somewhat more energy than you were really entitled to. As this just made the game more interesting, nothing was immediately done to correct it.

IV. AFTER SPACEWAR

The game was essentially complete by the end of April, 1962. The only further immediate work was to make **Spacewar!** presentable for MIT's annual Science Open House in May. A scoring facility was added so that finite matches could be played, making it easier to limit the time any one person spent at the controls. To provide for the crowds that we (accurately) anticipated, a large screen laboratory CRT was attached to the computer to function as a slave display. Perched on top of a high cabinet, it allowed a roomful of people to watch in relative comfort. Also in May, the first meeting of DECUS (Digital Equipment Computer Users' Society) was held in Bedford, MA. At that meeting I delivered the first paper on the subject, pretentiously titled " **Spacewar!** Real-Time Capability of the PDP-1."

Over the summer of 1962, the original **Spacewar** hackers began to drift away. Alan Kotok and I went to work for Digital. Steve Russell followed John McCarthy to Stanford University. Peter Samson and Bob Saunders stayed in Cambridge for a while, but eventually they, too, went west. Dan Edwards remained with the AI group for a few years, then moved to Project MAC, Jack Dennis and the PDP-1 also wound up at Project MAC, which evolved into MIT's Laboratory for Computer Science. Others took up the maintenance and development of **Spacewar!** Program tapes were already showing up

* Quoted in *Two Cybernetic Frontiers* by Stewart Brand (Random House, 1974)

all over the country, not only on PDP-1s but on just about any research computer that had a programmable CRT.

A Mystery, Just For Good Measure

Slug tells me that there is a Lost Version of **Spacewar!** There would be, of course. He says the game is pretty much like the original, but the scoring is much more impressive. After each game of a match, cumulative scores are displayed as rows of ships, like a World War II fighter pilot's tally. Slug says he saw this version for a short time on the PDP-1, but never found out who produced it or what became of it.

Twenty Years Later

The original Spacewar PDP-1 was retired in 1975 and put in storage at DEC's Northboro warehouse, where it serves as a parts source for the similar machine now on working display at Digital's Computer Museum in Marlboro, MA. At this writing, DEC engineer Stan Schultz and I are trying to put the original **Spacewar!** back into operating condition. So far, all attempts at finding the original control boxes have been futile; we will probably build replicas (the plastic Atari joysticks we have now got no class).

Dan Edwards still works for the U.S. Government, developing computer security systems. Alan Kotok is still a consulting engineer with DEC. Peter Samson is now director of marketing for Systems Concepts, Inc., in San Francisco. Bob Saunders had gone to Silicon Valley, where he is an engineer-programmer for Hewlett-Packard.

Jack Dennis is a Professor of Computer Science at MIT, in the Laboratory thereof.

Marvin Minsky is Donner Professor of Science in the Electrical Engineering Department at MIT.

John McKenzie, the chief engineer, is retired, but over the past year or so has been helping to restore the TX-O and PDP-1 to life at the Computer Museum.

And what of the Hingham Institute? Wayne Wiitanen has recently become a Senior Research Scientist at the General Motors Research Laboratory, where he is happily designing eyes for robots. Slug, after various adventures, is now a programmer-analyst for Interactive Data Corporation in Waltham, MA. I am reduced to writing for a living, but tend to act somewhat less superior therefor.

Spacewar! itself has bred a race of noisy, garishly-colored monsters that lurk in dark caverns and infest pizza parlors, eating quarters and offering degenerate pleasures. I think I know a few former hackers who aren't the slightest bit surprised.

Acknowledgements

I was able to reach all of the original **Spacewar!** perpetrators, hackers and Hingham Institute Fellows alike. Not to mention Professors Dennis and Minsky, and John McKenzie. In addition, I am grateful to Marcia Baker, Professor F.J. Corbato, and Professor R.M. Fano, all of MIT, for help with dates and places, and other facts. The help was theirs; any mistakes are mine.

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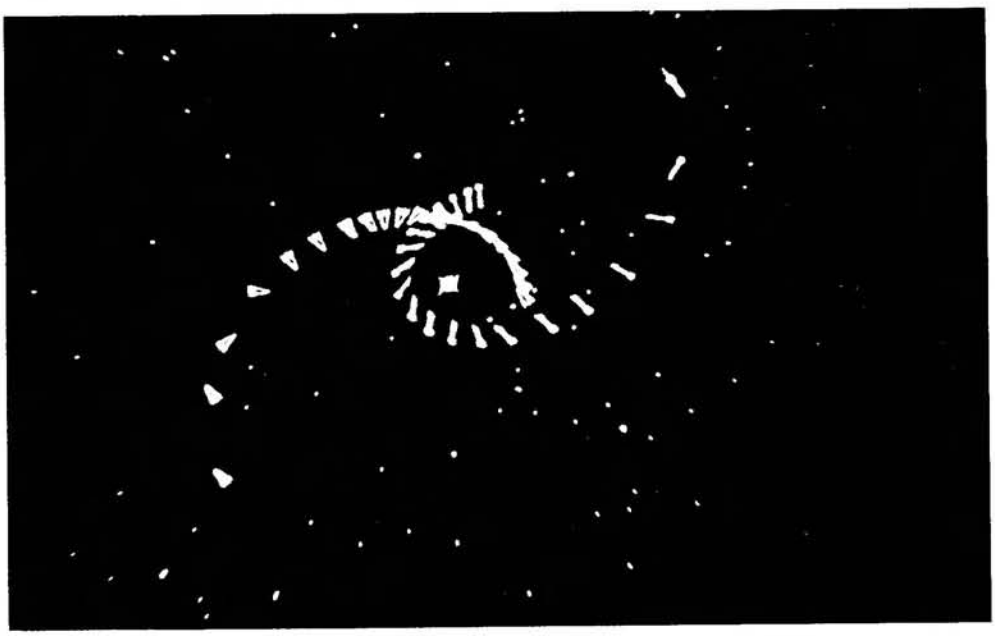
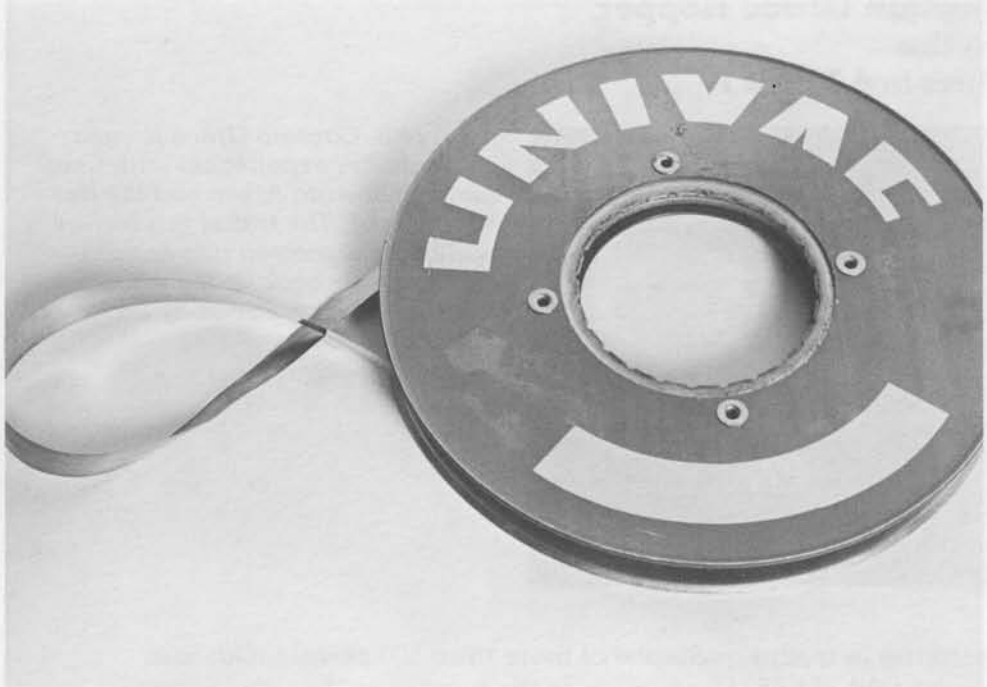


Developing Univac's Plated Thin Film Metal Recording Tape

Ted Bonn, April 17, 1983



While I was at the Moore School of Engineering at The University of Pennsylvania, I took a course with John Mauchly. Then, after I received my Masters degree, Eckert made me an offer. In early September 1947, I climbed to the second floor over a haberdashery in downtown Philadelphia and started to work in the offices and labs of the Eckert-Mauchly Computer Corporation.

Since available acetate base tape materials and magnetic laquer coatings were not good enough, I was assigned to develop plated thin film metal magnetic recording tape for the Universo I. We chose ½" wide phosphor bronze tape as the substrate. I knew nothing about plating or magnetic alloys. My starting point was the fact that someone in the Brush Development Company had learned how to electroplate nickel iron permalloy and someone at the Bureau of Standards had learned how to deposit permalloy chemically without current. Since plating was a chemical process I obviously needed a lab with a fume hood, water drains and so forth. One powder room became my lab and the other was left for its intended purpose. The window would be opened to clear out fumes. I would get water out of the sink and the toilet was an ideal drain. Of course, I had to be sure to flush a couple of times when I dumped in acids so that they would not eat the pipes. Being an electrical engineer I would frequently miscalculate the amount of ammonium salts needed and the room would fill with fumes. Then I would throw up the window and stick my head out. But occasionally the door would be opened and the wind would be blowing in the wrong direction, then all Eckert-Mauchly would fill with ammonia fumes.

The chemistry went faster than the electronics. We could deposit a film before we could measure its magnetic properties. We made a piece about three feet long, soldered the ends together to make a loop and mounted it on a loop tester. We tried to record on it. John Mauchly was excited and right at my shoulder. No output. I checked the electronics, and the head, and the write current. Still nothing. Then John remarked that there appeared to be a signal at the joint where the two ends of the tape were soldered. I had seen it too, but it didn't look like a recording signal and I ignored it. John correctly interpreted it as a signal caused by improved magnetic properties due to the heat of soldering. His astute observations started me on a series of experiments on heat treating tape. It was not the final answer, but it was a key answer along the way.

I built a pilot production line and Reed Stovall built and debugged the actual production equipment. The same thin electroplated magnetic film was used by Univac on the LARC drum and on the Fastrand, and many other recording drums and discs throughout the industry. Plated tape was used exclusively with the Univac systems until about 1956 or 1957 when mylar base and epoxy resins became available.

You could see the holes in cards, but we had difficulty convincing some people that there was actually information recorded on the tape, since there is no visible difference between recorded and unrecorded tape. So we made the recording visible. Fine magnetic particles were suspended in a solvent and applied to the tape. The particles were attracted to the magnetic poles and when the solvent evaporated you could clearly see the recorded information. The tracks and the interblock gap stood out. You could pick the pattern up with scotch tape and apply the tape to paper and carry it around to demonstrate.

The design of the tape handler, called "Universo," set the standard for the industry. It featured 100 inch per second tape speed; 120 bits per inch recording density; eight tracks on half-inch wide tape for a data rate of 12,000 characters per second; a start/stop time of 10 milliseconds, this meant the 720 digit block could be recorded in 5.6 inches and the interblock gap was only 2.4 inches long. Thus the Eckert-Mauchly team established magnetic tape as the high speed input/output medium for computers and designed and successfully produced a complete line of magnetic tape based peripherals.

This narrative explanation given by Ted Bonn at a Sunday Bits and Bites talk corrects misinformation printed in the Summer Report (Page 16) describing the UNIVAC tape.

Captain Grace Hopper on the Harvard Mark I

April 14th, Captain Grace Hopper spoke on her experiences with Commander Howard Aiken and the Harvard Mark I. The text of this lecture will be incorporated into her contribution to a book on the same subject that is being edited by Professor I. Bernard Cohen.

Speaking to a rapt audience of more than 500 people, Captain Hopper told of her introduction to the machine: "Aiken waved his hand at Mark I, all 51 feet of her, and he said, 'That's a computing engine.' Not a computer. Not a calculator. And there's a difference in the concept that was in his mind as well. Computers are what we have nowadays, black boxes, one unit, one thing. Calculators were those wonderful things you sat on your desk and then you ground out the answer, you moved the register, ground some more. I think when he said computing engine, he was referring to its different parts that took on different functions. That's a concept we've lost that we'll need to bring back again, because we'll be building systems of computers with different functions. He was right when he called Mark I a computing engine; it had many parts that worked simultaneously together with each other and performed functions."

"Howard Aiken was a tough taskmaster. I was sitting at my desk one day and he came up beside me, and I got on my feet real fast. He said, 'You're going to write a book.' I said, 'I can't write a book.' He said, 'You're in the Navy now.' And so I wrote a book. I have it here with me so that I can answer any questions. This is the Mark I manual, the entire bible for Mark I. You could take this and build Mark I again, if anyone felt like it."

Spring Events

After dinner, Museum Director Gwen Bell and Board Chairman Ken Olsen chat with Board member George Michael.

First Anniversary Dinner and Talk by C. Lester Hogan

May 5th, more than 150 people gathered at the Museum to celebrate its first anniversary with a reception, gala dinner and a talk by C. Lester Hogan. Clark Prestia, the donor of our typewriter collection came from California, G.C. Belden from Rochester, New York, and members of the Board of Directors converged from all directions. Conversations overheard at the reception were, "Oh, my gosh, I haven't seen you since . . ."

C. Lester Hogan, who has been involved with development of semiconductors since his days at Bell Labs in the fifties and early sixties, described the origin and evolution of the semiconductor industry, and gave some insights of a view to the future.

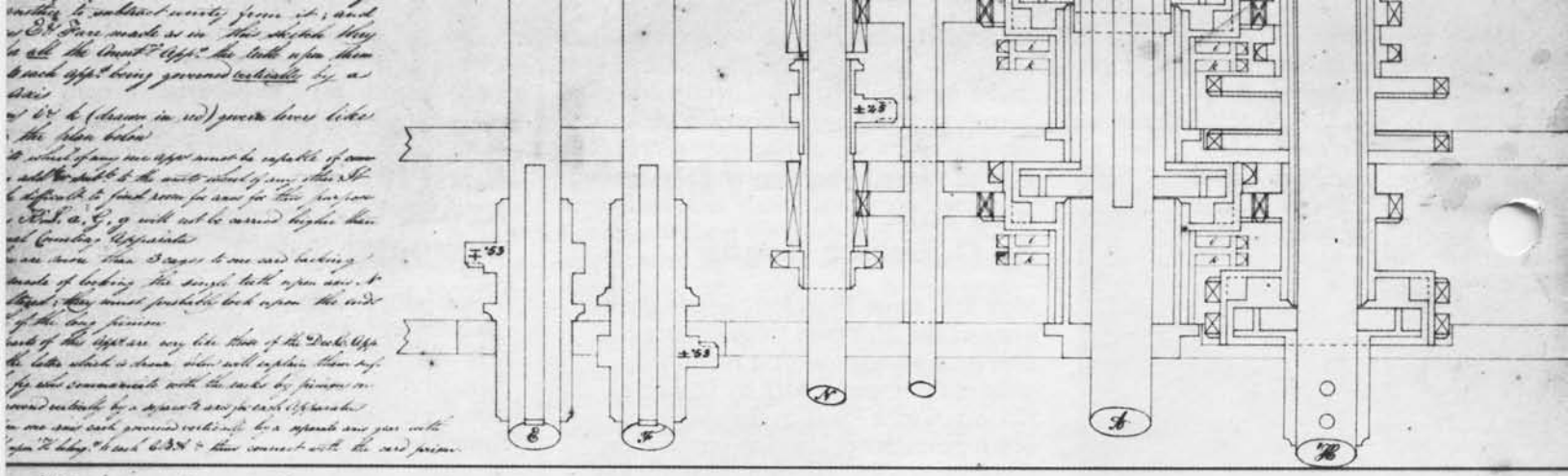
Dr. Hogan congratulates Jamie Parker on the new semiconductor exhibit researched by Hugh Plant and John Breen (background). C. Lester Hogan, past president of Fairchild Camera and Instrument, was responsible for a donation of Fairchild's significant chips and their photographs to the Museum. Under the direction of Jamie Parker, John Breen and Hugh Plant developed these into an exhibit emphasizing critical steps in the evolution of semiconductors. Breen and Plant, students at Worcester Polytechnical Institute, produced the exhibit and supporting text as their "Interactive Qualifying Project." It received the highest grade from Worcester Polytech and from Dr. Hogan.

April 10: Apollo Guidance Computer Talk

Describing the Apollo Guidance computer at a spring "Bits and Bites" talk are (left to right) Albert Hopkins, Ramon Alonso and Eldon Hall, designers of the on-board guidance computer.

"The Apollo Guidance Computer project was a perfect example of top-down design in which the requirements are set and the job carefully described. The first thing that was decided was how big it was going to be, so Eldon Hall went to North American Aviation and returned with the answer: 'It is this big.' We felt like rookies. We were going to fill a cubic foot with computer and hope it would do the job," Alonso told the "Bits and Bites" audience.

"During the design process we had the opportunity to meet astronauts, most of them Mercury astronauts at the time. They listened to what we had to say, and then they told us, some politely and some not so politely, that the first thing they were going to do was indeed turn it off. In the first place, nobody was going to fly their airplane, in the second place they didn't trust it. But people get used to everything, including computers and spacecraft," Alonso said.



All the figure wheels of all the Counting Apparatus are upon the axis A. If the bowl socket on A is moved vertically — or + 3 and then moved circularly it brings the units wheel No 1 or 2 of the Store Counting Apparatus No 1 to zero; and if it is moved vertically — or + 6 it brings No 1 or 2 of both units & tens of Store Counting Apparatus to zero.

The axis A does the same by Store Counting Apparatus No 2.

If the socket belonging to Decimal Counting Apparatus No 1 is moved vertically — 3 and then moved circularly it reduces the units wheel alone to zero; if moved vertically — 6 it reduces both wheels to zero.

The socket belonging belonging to Decimal Counting Apparatus No 2 does the same by its wheels.

Each of these sockets is to have its vertical motion governed by a separate axis; these axes are not shown in the drawings.

The Store Counting Apparatus commences with the racks of the stores by means of the pinions upon the axis B; those for Store Counting Apparatus No 2 being governed by the axis D.

The Store Counting Apparatus are enabled to give and retain by the pinions on the axis G and dead center g.

The pushing up section (Drawing 32) does the same I by the bowl wheel W and by means of the wheels 5, 7, 8 transfer the number of digits to the Decimal Counting Apparatus No 1 either additively or subtractively; and transfer in the same manner to Decimal Counting Apparatus No 2 by means of the wheels 9, 8 and 10.

The axis H enables the bowl wheel of either of the Store Counting Apparatus to communicate either additively or subtractively with the bowl wheel of Decimal Counting Apparatus No 2.

The axes P Q R S T U and V are for governing the vertical motions of the wheels p, p; q, q; 10; 27; 8; 8, 7, 8, 9 & 10 and are not shown in the elevation.

S governs the vertical motions of the carrying teeth of Decimal Counting Apparatus No 1 and T governs the vertical motions of the carrying teeth of Decimal Counting Apparatus No 2. T is not shown in the elevation.

E and F have the single teeth upon them for counting off the number from Decimal Counting Apparatus; these are not shown in the elevation. (Perhaps one of these may be found sufficient with a tooth upon it governed vertically by another axis)

H, H, 2H are locking axes; they are not shown in the elevation.

The wheels on b in the tens axis are locked by a cam on 2H.

I is an axis for putting out the wires carried by the levers c & f, which are put in by the Decimal Counting Apparatus running up. I is not shown in the elevation.

The wires carried by levers b & c are put in by Decimal Counting Apparatus No 2 coming to zero and one or both are out when it is at any number.

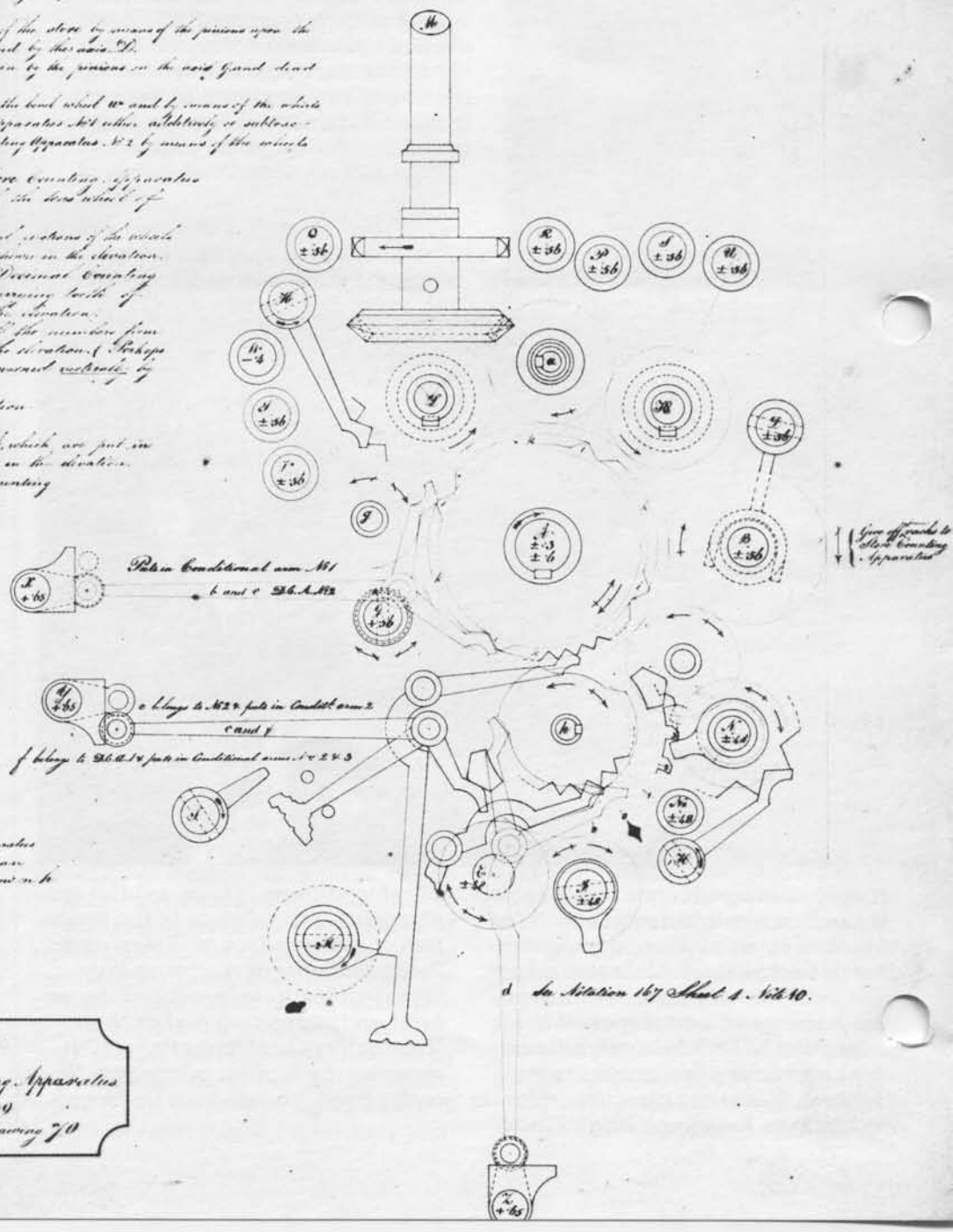
The wire of d is put in by the tens wheel of Decimal Counting Apparatus No 2 moving from 3 to 2 and remains in at 4, 3, 2, 1, 0. This is for the purpose of detecting the fact of there being more figures in the product than the machine can hold, which is done by the wire of d rising of the figure wheels stand at a number 6 or than 60; (60 = Compt of 40 which is the greatest number the machine can hold) the cams which govern c are only shown in part to avoid confusion of lines.

d is not shown in the elevation.

X, Y, Z are lifting axes X only is shown in the elevation.

After this drawing was made it was proposed to put the Combinatorial Counting Apparatus upon the axis A which may probable be done by a little alteration in the positions of the axes in the Plate.

For bringing the wheels of the Combinatorial Counting Apparatus to zero in connection with cards, it was proposed to make A an axis like I on drawing 33, and to put the wheels that are now on A upon fixed sockets in which I would turn.



d Sa Notation 167 Sheet 1. Nº 10.

Plan of
Decimal & Store Counting Apparatus
10 July 1839
Elevation in Drawing 70

PRAY, MR. BABBAGE . . .

A character study in dramatic form

by Maurice Wilkes

Mr. Babbage's library in his house at 1 Dorset Street, London, is a comfortable apartment, as it needs to be, for he spends much of his time in it. It has the usual trappings of a library, including bookcases, a writing table, and leather armchairs. By the side of the fireplace—which has no fire—is a bell handle of the usual rotary type. The door is at the rear, and on one side of it is a small oval looking-glass in a gilt surround. On the other side there is a just discernible mark on the wallpaper, suggesting that at some time a similar looking-glass has hung there.

The date is 19 November 1856, and Mr. Babbage is 65 years old. His wife died young and for the last thirty years he has lived by himself. His loneliness has been accentuated by the circumstance that his two elder sons have migrated to Western Australia and his youngest son—of whom we shall hear more—is in the service of the East India Company.

As long as anyone can remember, Mr. Babbage has been working on a vast mechanical digital computer—which he calls his Analytical Engine—but has never succeeded in producing anything that would work. In consequence, the world has written him off as a crank, a verdict that history will one day triumphantly reverse. He is given to complain to anyone who will listen that, in spite of having expended much effort and a considerable fortune on the Analytical Engine and on the Difference Engine that came before it, he has received nothing but rebuffs in his own country—particularly from the Government—and that he is better appreciated abroad. Nor is he free from the Victorian failing of indulging in personal vendettas, conducted in print, with those who have crossed his path. However, you would be very wrong if you were to think of him as an embittered and isolated man. Far from it. He is socially a great success. He knows everybody, goes everywhere, and is at no loss for friends. He may dislike being contradicted and may be more than a little pompous in manner, but keep him off his hobby horses and you will find him an entertaining enough companion. However, when we first meet him, it is his number one hobby horse that he is riding.

At this moment, Mr. Babbage is standing in his library facing his solicitor, Mr. Charles Few, who is comfortably seated in one of the armchairs. Mr. Babbage listens, with growing indignation, as Mr. Few reads from a bundle of legal-looking papers.

Editors note:

The Computer Museum presented the premier performance of Pray, Mr. Babbage . . . *by Maurice Wilkes on December 10, 1982. It is a character study in dramatic form of Charles Babbage. An English mathematician, 1791–1871, Babbage invented the first programmable computer—the Analytical Engine. Although it was never built, the Analytical Engine was the first computer ever designed. It was a machine without a fixed purpose, designed to do any calculating task the owner wanted it to. Babbage also designed the Difference Engine, an advanced mechanical device for calculating tables of mathematical functions.*

Characters in order of Appearance

Charles Babbage	
Charles Few	Solicitor
Payne	Manservant
Sir Edward Ryan	Brother-in-law and life-long friend of Charles Babbage
Henry Babbage	Son of Charles
Min	Henry's wife

SCENE ONE

Few: Middlesex. Dominico Beltoni by Thomas Johnson, his attorney, sues Charles Babbage for that the defendant assaulted the plaintiff and gave him into custody to a policeman and caused him to be imprisoned in a certain police station and to be conveyed there in custody through and along divers public streets to a Police Court and to be there a long time, to wit, from Saturday to Monday, further imprisoned. Thereby the plaintiff incurred great expense in procuring his liberation from such imprisonment and has lost divers gains and profits. And the plaintiff claims 50 pounds.

Babbage: Fifty pounds!

Few: That is what he demands.

Babbage: It is preposterous. During the last ten years the amount of street music has so greatly increased that it has become a positive nuisance to a considerable portion of the inhabitants of London. It robs the industrious man of his time; it annoys the musical man by its intolerable badness; it irritates the invalid, and destroys the time and energies of all the intellectual classes of society by its continual interruptions of their pursuits.

Few: I agree with you, Sir, but unfortunately there are many people who don't. Some of your neighbours, I believe.

Babbage: The great encouragers of street music belong chiefly to the lowest classes of society. Of these, the frequenters of public houses and beer shops are the worst. I have obtained an unenviable reputation by my determined resistance to the tyranny of the lowest mob, whose love of the most discordant noises is so great that it insists on enjoying them at all hours and in every street.

Few is about to reply when the manservant enters.

Manservant: Sir Edward Ryan has called, Sir, to enquire when Mr. Henry and Mrs. Henry are expected. He will be happy to wait if you are engaged or could call back later.

Babbage: Ask Sir Edward if he will be good enough to step in. (Manservant goes out) You are acquainted with my brother-in-law, I believe. He is a former Chief Justice of the Presidency of Bengal. His advice will be germane.

The manservant returns and holds the door open for Ryan. Ryan is of exactly the same age as Babbage, and they were at Cambridge together. His long career in public service has given him an easy touch in dealing with people that Babbage conspicuously lacks. Also, he did not have the misfortune to lose his wife at an early age.

Ryan: Good afternoon, Charles. (Sees Few) Good afternoon, Mr. Few. (Shakes hands) (Looking quizzically at Babbage) Mr. Babbage closeted with his solicitor! Organ grinders, I presume.

Babbage: I am the victim of much persecution, Edward, as you know. An Italian musician of the name of Beltoni is demanding 50 pounds damages of me.

Few: Beltoni refused to stop playing and go away when Mr. Babbage desired him to do so. He became abusive and Mr. Babbage fetched a policeman and gave him in charge. The magistrate dismissed the case and found him to be not legally in custody.

Babbage: I despair! This new magistrate has yet to convict anyone I bring before him. His predecessor was bad enough, but this one seems to regard all street music as high art!

Ryan (To Few): Do the Metropolitan Police Acts sanction the giving of a man in charge in these circumstances?

Few: They do not.

Ryan: I do not know whether you want my opinion, Charles, but it seems to me that you will have to ask Mr. Few to make as good a settlement as he can—out of court.

Few: I would certainly urge that as the most prudent course. A present settlement is infinitely cheaper than fighting a case, even if one is likely to win.

Babbage: Well . . .

Babbage, faced with this solid front, pauses to consider, and he may be on the point of agreeing when a barrel organ opens up with "Rule, Britannia" outside his window. He moves in a determined but dignified manner to the fireplace and rings the bell.

Babbage: You see how this intolerable nuisance starts up at the most inopportune moments and destroys all concentration. On a careful retrospect of the last dozen years of my life, I calculate that one fourth part of my working power has been destroyed by it. Wh my daughter-in-law was in a delic state of health after the birth of her son, I could do nothing to protect her from incessant annoyance. The present interruption could continue for a protracted period.

He rings the bell again. As he does so, the music stops.

Babbage: (Taking a memorandum book from his waistcoat pocket) Pray excuse me. I keep a careful record of each and every occasion on which I am disturbed. (He writes in the book)

The manservant enters.

Manservant: I crave your pardon, Sir, for not answering the bell immediately, but I thought it would be your wish that I should desire the person to go away.

Babbage: He was abusive, I presume.

Manservant: Well, Sir, not exactly abusive, as you might say. When I offered him a shilling to go away, he merely observed that you did not know the value of peace and quiet, and demanded another sixpence. (He goe out)

Ryan: When you bought this house I seem to remember that the neighbourhood was a quiet one.

Babbage: It was. I chose the house for that reason, and because it had an extensive plot of land on which I could erect the workshop and drawing office I needed for my work on Calculating Engines. Unfortunately, despite all protests, the street was invaded by a hackney coach stand. The immediate consequence was obvious. The most respectable tradesmen, some of whom I had dealt with for five and twenty years, sold their property and left. Coffee shops, beer shops, and lodging houses filled the adjacent small streets. The character of the new population may be inferred from the taste they exhibit for the noisiest and most discordant music.

Ryan: Have you thought of leaving yourself?

Babbage: I may yet be forced to do so. But it would mean the end of my wor Why should I be driven from a hous on which I have expended a considerable fortune, and which exactly suits my purposes? I have provided many comforts. For example, soon after com-

ing here one of my first steps was to install Mr. Perkins' patent hot water warming apparatus.

Ryan: Ah, there you have something out of the ordinary. A home that is always comfortably warm, whatever the weather.

Few: I noticed it as soon as I came in. Even the entrance hall is warm. I hope, Sir, you will pardon my curiosity as to how it is contrived.

Babbage: It is very simple. There is a furnace in the cellar, and pipes of welded iron filled with hot water convey heat to the various parts of the house.

Few: The usual function of a fire in causing the air in a room to be renewed does not seem to be missed. I detect no lack of ventilation or odour of burnt air.

Babbage: I agree with you, Sir, that ventilation is of equal importance to heating. Mr. Perkins, by my direction, provided for fresh air to be admitted from the garden and conveyed by ducts to the several rooms; it emerges after being heated by the pipes. My desire was to secure uniform warming and ventilation, with strict economy of fuel.

Ryan: How much fuel do you use, Charles?

Babbage: During the winter of 1838, I caused my servant to keep accurate records. From 30 to 85 pounds of strong coke were consumed in 24 hours, depending on the temperature outside.

Ryan: Certainly the system produces much comfort. I believe the time will come when every gentleman's house of the better sort will be warmed in this way.

Babbage: You understand why I do not wish to leave Dorset Street. In any case, there are street musicians to be found everywhere. I compute that there are no fewer than one thousand of these artists plying their abominable trade in London at any one time. If the Metropolitan Police Acts do not help, is there any other remedy open to an honest citizen?

Few: Well, there is the common law. It would be possible to seek counsel's opinion as to the propriety of applying to the magistrate to state a case for the Queen's Bench. What do you think, Sir Edward?

Ryan: It would be possible, certainly. I would not like to say what the outcome would be. The only thing that is certain is that it would cost you a great deal of money.

Babbage: How much?

Few: I would say about 50 pounds. But in addition, there is Beltoni's action to be defended. I suppose you would wish to have that case heard before a Special Jury. That would cost you 20 pounds, which you would have to pay whether you won or lost. Altogether for the whole affair between 50 and 100 pounds, perhaps near a hundred.

Babbage: No amount of common sense will enable a man to comprehend the laws of England. But it would be good economy to purchase my own time at the expense you mention. Pray take all necessary steps without delay. You will be willing to give Mr. Few the benefit of your advice, will you not, Edward?

Ryan: Certainly. (To Few) You will find me either at the Civil Service Commission near Westminster Abbey or at the Audit Office nearby.

Few: Thank you, Sir Edward. I will call on you as soon as I have drafted a brief for counsel. All is now settled, I think. I will get back to my chambers. Goodbye, Sir Edward. Goodbye, Mr. Babbage.

He shakes hands and goes out. Babbage and Ryan slip into the easy manner of old friends who were at College together.

Ryan: I called hoping to see Henry and Min, Charles, but I gather from your man that you are not expecting them until later.

Babbage: No. They have gone to Folkestone to leave the children with Min's Aunt Rachel.

Ryan: Yes, they told me they were going to do that when they came to see me last week. We said goodbye then, but, as I had an hour to spare, I thought I might catch them again. Min will be miserable at parting with the children.

Babbage: It is very hard on her, but taking them back to India was out of the question.

Ryan: Oh, absolutely. Where they are going in the Punjab is a very inaccessible place, not at all suitable for a baby of one and a little girl of four. They will be able to travel by carriage as far as Uballa, but beyond there they will have to go by doolie, a most uncomfortable form of travel.

Babbage: Yes, Henry has described it to me. A doolie is a variety of sedan chair, is it not, fixed to a pole and carried on men's shoulders?

Ryan: A long box, really; it is big enough to recline in but, believe me, one is very stiff and worn out at the end of the day. Henry was telling me that he expects to be appointed interpreter to his regiment.

Babbage: Yes. It is very gratifying to me that my son should have been so successful in his profession. It has been entirely on his own merits. I have used no interest whatever on his account. He qualified as an interpreter after less than two years' service in the Indian Army.

Ryan: He is a very good one, too. He coached my son in Hindustani, you remember. (Looks at his watch) I fear I must go now. I have to be at the Exchequer in twenty-five minutes.

Babbage: And I shall just have time to do some work on my Analytical Engine. My workmen will need fresh instructions tomorrow.

Ryan: Ah, there you have something that interests you. I sometimes wish I had kept to science instead of turning to the law when I left Cambridge.

Babbage: (Grimly) You would have been poorer for it.

Ryan: I suppose I would. Our fellow student, John Herschel, did not do too badly, though. But then he was Senior Wrangler; that makes a difference. Goodbye, Charles. Give my good wishes for their journey to Henry and Min. (He turns to go but looks back) By the way, what was that question you were asked? Pray, Mr. Babbage, if you put the wrong figures into your machine, will the right answers come out? By a Member of Parliament, too! (He goes out chuckling)

When Ryan has left, Babbage goes to his writing table and begins to spread out some large sheets of paper. A thought strikes him, and he crosses to the fireplace and rings the bell. He returns to the writing table and starts to work. The manservant comes in.

Manservant: You rang, Sir?

Babbage: Yes. Mr. Henry and Mrs. Henry are leaving early tomorrow morning. We shall require an early breakfast—say six o'clock.

Manservant: Very good, Sir. (He prepares to leave)

Babbage: Oh, and Payne—

Manservant: Yes, Sir?

Babbage: Be sure to go for a cab in good time. I shall accompany Mr. and Mrs. Henry to Waterloo station and see them into the train.

Manservant: Very good, Sir.

Babbage settles to work, writing on one of the sheets while referring to the others. Very shortly, the noise of a hackney cab is heard and it is clear that Henry and Min are arriving. Babbage gives a sign of annoyance at having his work interrupted. He continues, and after a few moments Henry comes in. As might be expected of an officer in the service of the East India Company, Henry, who has recently celebrated his 32nd birthday, has a soldierly bearing, although he is lightly built and of medium height.

Babbage: You are earlier than you said you would be, Henry.

Henry: Yes, the train left sooner than we thought. Min has gone to take her coat off. She will be down in a minute. (Seeing the work on Babbage's table) I am afraid I interrupted your work, Sir.

Babbage: I was working on the notation for my new method of multiplication by means of precomputed multiples—the one we talked about before you left. I am not sure even now that I have achieved the best possible, but you will see that I now take three fewer turns of the hand than before. (Putting the paper he had been working on in Henry's hand, he goes out on some brief errand, leaving the library door open. Henry studies the paper with signs of approval as he proceeds.)

Min enters. She will be 23 in a few days' time, having been only 18 when Henry met her on a river steamer in Central India and married her in the garrison church at Mirzapur shortly afterwards. She is, as we shall see later, a true Memsahib. At present, however, as she stands in the doorway, she looks very young and helpless.

Henry: (Going to her) Are you all right, Minnie?

Min: Yes, but I have just been up to the nursery. How empty it is! Oh, Henry!

Henry just has time to squeeze her hand and give her what comfort he can before Babbage returns.

Min: Never mind. I shall be all right.

She pulls herself together, and no-one would know what she is feeling.

Babbage: Ah, there you are, my dear. (He takes her hands in his) Back just in time to say goodbye! If only you were not leaving tomorrow. (It is obvious that he is very fond of her, although he does not quite know how to show it)

Min: Yes, it is sad we are leaving. The time had to come, I suppose. I have been so happy here. Thank you for everything. The nursery with so many conveniences, and—

Babbage: You have put me in your debt. It is a great boon that you have conferred on me—both of you—by coming and joining in all of my pursuits. I shall be very miserable when you have gone.

Min: You have done so much for us.

Babbage: And it has given me great satisfaction that my son should have entered so fully into my work.

Henry: If only I could have found some feasible way of leaving the Indian Service and staying in England! I could find nothing tempting enough, or certain enough, to entertain, especially as we now have the children to think about.

Babbage: Yes, I too had hoped . . . It is hard to believe that I shall not have you and the children with me anymore. At any rate, they will be well looked after. They will be under the eye of your aunt, and you have every confidence in Jane. You need not worry about them in any way. (To Henry) You remember the time when Jane came running downstairs to tell us Harry had been born? We were at dinner.

Min: (Half to herself) It was just a year ago.

Henry: Yes, how glad we were that it was a boy. I shall be eligible to apply for a Civil appointment later this year. If I could contrive to be posted to one of the larger stations, it might be possible for the children to join us. It would be out of the question where we are going. The journey, for one thing...

Babbage: It would be a great convenience to you if the new railway from Calcutta to Delhi were open.

Henry: Yes, it would, indeed. Min and I have just been talking about it. I was telling her of the deep interest you took in railways when I was still a boy.

Babbage: (To Min, eagerly taking up the topic) Yes. I naturally became interested at the commencement of the railway system, not only for its bearing on mechanism, but also for its bearing on political economy.

Min: Henry told me that you did some experiments on the Great Western Railway.

Babbage: Yes, I did. It was the wish of Mr. Brunel and the directors that I should give my opinion on the question of the gauge, and I felt that I could not speak with confidence without making certain experiments. The directors put at my disposal a disused second class carriage which I fitted up with recording apparatus.

Henry: And the experiments confirmed you in your view that the broad gauge was to be preferred.

Babbage: They did. I have been told that the statement I made at a meeting of the proprietors held at the London Tavern had a considerable influence in their decision to adopt the broad gauge.

Min: That was the 'battle of the gauges,' wasn't it?

Babbage: Yes. Strong feelings were held on both sides. The battle has long since been won by the standard gauge, as it is now called.

Henry: Do you wish, Sir, that you had advised the Great Western Railway in the opposite sense?

Babbage: No, I do not. It is still my decided opinion that all the advantages of economy of management, as well as of safety, lie with the broad gauge.

Henry: But the inconvenience and expense of converting to the narrow gauge has been great.

Babbage: True, but at the time no one could foresee that Mr. Stevenson's influence in favour of the narrow gauge would prevail.

Henry: He was the father of the railways, when all is said. I would have thought . . .

Babbage: (Who does not like being contradicted) I have given you my opinion. Even a few inches more than 4 feet, 8½ inches would have been preferable. Mr. Stevenson himself admitted as much to me at the British Association meeting in Newcastle.

Henry: His son has adopted 5 feet, 6 inches for the Calcutta railway. That is quite a lot more—9½ inches.

Babbage: It is certainly an improvement.

The manservant enters.

Manservant: Excuse me, Sir. Mr. Wight was hoping that you would have time to go to the workshop before he leaves.

Babbage: Oh yes, I will go now. Perhaps you would like to come too, Henry. I think that you would be interested in my latest experiment.

Henry: I am sure I would, Sir. I will come along directly.

Babbage goes out.

Min: It has been a wonderful three years furlough. We have done so many things, seen so many people, haven't we?

Henry: Yes, we can indeed look back on it with pleasure and satisfaction. I have lost time for my pension, and we have spent some of our savings, but it has been well worth it.

Min: And yet, when we left India, you were by no means sure that it would be agreeable to your father to have us in his house.

Henry: No. During my furlough I have met him on more equal terms than ever before. As a boy I feared him, and often left the house to avoid meeting him.

Min: That was when you lived with your grandmother?

Henry: Yes. She was much affected when I left for India. My father said goodbye to me here in his library and did not even come down to the cab. I could not help contrasting my experience with that of another cadet travelling in the same ship. His father went down to Portsmouth to see him aboard. Still, I did learn to respect my father during that period, and earning his approval became important to me. It was with great satisfaction that I wrote to tell him that I had qualified as an interpreter.

Min: You have done other things to please him while you have been here, Henry. For example, the drawings of the Swedish Difference Engine that you took to the British Association meeting at Newcastle.

Henry: I wish I could do something to make my father's work on calculating machines better understood. People confuse the Analytical Engine with the Difference Engine.

Min: It is a pity that the Difference Engine was never completed.

Henry: Yes, people naturally criticise my father for abandoning it. But it was a big advance that he had made in going to the Analytical Engine.

Min: But when the government had spent so much on the Difference Engine, it should have been completed. Surely the disagreement your father had with Mr. Clement, his engineer, could have been overcome.

Henry: Yes, you are quite right. But anyone who properly understands the principles on which the Analytical Engine is based can hardly doubt its value to science as a whole—whereas the Difference Engine—

Min: But how many people do understand the Analytical Engine?

Henry: Not many, it is true. And there are many practical problems still to be overcome in its construction.

Min: Will your father succeed in completing it, do you think?

Henry: He still has a long way to go. The important thing is that he should go far enough for others to be able to continue the work. I wish he would publish a full account of the various principles and contrivances that he has evolved.

Min: The memoir by Menabrea that Lady Lovelace translated and annotated does not go far enough?

Henry: No, and it does not make easy reading.

Min: Have you suggested to your father that he should prepare a full account?

Henry: I have several times resolved to do so, but I have felt diffident about approaching the matter.

Min: Yes, I understand that. But if you do not say something you will regret it later. Perhaps you could take an opportunity tonight when I have gone to bed. I shall go early in any case.

Henry: You are right, I should. I have felt very close to my father during these last months. He took to you, too, Min, at once. You remember the looking glass he placed on the sideboard so that during dinner he could see you in it without looking in your direction? It is still there.

Min: Yes, I had to pretend not to notice it. I took to him too, Henry. He is a bit of an ogre in some ways, but underneath very nice and very sincere. I suppose that is why he has so many friends, and goes so much into society.

Henry: It is unfortunate that he has also made some enemies. He is apt to take an unfortunate view of other people's actions and motives. When he does he feels that he must expose them in strong terms.

Min: (With a little laugh) As far as strong terms go, he has met his match in the Reverend Charles Sheepshanks. What was it he said in his pamphlet about Mr. Babbage's blundering pertinacity?

Henry: He attributed it to a diseased mind! He also said that my father was ill-natured.

Min: Oh, that he never is. How could anyone say that he is ill-natured?

Henry: My mother's dying when I was a baby had a lasting effect on him. He has lived alone all these years.

Min: How glad I am we named Georgie after her, Henry. I am sure it gave him pleasure. (The thought of her little girl

causes her grief to come flooding back) Oh Henry! When will we see her again?

He goes to comfort her, but there is nothing he can say. She abandons herself to grief for a moment, but then remembers who she is, and the stern duty that fate has laid on her.

Min: I can bear it. Separation from her children is something that all women in my situation must endure. (She pulls herself together and moves away from him) I must talk to Payne about the things that were to be sent to Folkestone. You ought to join your father in the workshop.

Henry: Yes, you are right. I will send Payne to you.

He looks tenderly at her, half hesitates, and goes out. Left alone, she goes over to the looking-glass, wipes her eyes and tidies her hair. She is quite composed when the manservant comes in.

Manservant: You wanted to see me, Madam?

Min: Yes, it was about the children's clothes.

Manservant: They are packed and all ready to be sent off, Madam. The housekeeper asked me to say that she has given away the clothes the children have grown out of.

Min: That is very kind of her.

Manservant: Will you permit me to say, Madam, that all of us downstairs wish you a good journey back to India.

Min: Thank you. I fear that you must have had much extra work during the last three years. We are very grateful to you for all you have done for us.

Manservant: It has been our pleasure, Madam. This old house has been a different place with children in it. I hope Jane will bring them to see us sometimes.

Min: I am sure she will.

Manservant: Perhaps you and Mr. Henry will be coming back, Madam?

Min: We would like to, of course. But India is a long way off, and travel is so very difficult.

Manservant: Yes, Madam. Seeing that I was interested, Mr. Henry described it to me, and showed me on the map where you are going. Will there be anything further, Madam?

Min: No, nothing more, thank you Payne.

SCENE TWO

A lamp is burning on the library writing table and the manservant is in the act of lighting another on the opposite side of the room. Babbage enters, followed by Henry.

Henry: You will excuse Min, Sir, for going to bed so early. She is feeling miserable at leaving, and we have to get up early tomorrow.

Babbage: We were all three miserable at dinner, I fear.

Henry: (Picking up some small objects from the writing table) I presume that these are the results of your latest experiments in casting small wheels, or rather in moulding them under pressure.

Babbage: Yes, they are. It is very necessary to my plan that I should have the means of making large numbers of identical parts cheaply and with precision.

Henry: (Putting the wheels down and resolving to approach the matter that is on his mind) May I ask, Sir, whether you have plans for adding to what is already in print about the Analytical Engine?

Babbage: No. The memoir by Menabrea and the notes that Lady Lovelace appended to her translation of it fully dispose of the mathematical aspects of the engine.

Henry: But the details of the mechanism? I could wish that you would write more on that subject.

Babbage: I have not the time.

Henry: It would be unfortunate if a future generation had to rediscover what you had learnt.

Babbage: My best means for ensuring that they do not is to complete the engine.

Henry: But the engine itself will only exhibit the one system you have decided to adopt. A critical discussion of the various possibilities you have considered, and your reasons for proceeding as you have done, would be of interest to many people.

Babbage: I can hardly undertake to discuss all my rejected arrangements until I have shown that the one I have chosen will meet the demands put upon it.

Henry: So you do not feel disposed to add to what has already been published?

Babbage: Not at present. At a future time, perhaps.

Henry: I must, indeed, agree with you that the Memoir and Notes give very full information about the mathematical use of the engine—that is, to those who are willing to give them the necessary study. I could wish that more men of science had done that.

Babbage: English men of science yo mean! I have been entirely without recognition in my own country. The Commissioners for the Exhibition of 1851 ignored the Difference Engine and its inventor. As for the Analytical Engine, I have received no return whatever for the time and energy I have expended on it.

Henry: I know you feel that you have been unjustly used in regard to your work.

Babbage: A report persistently circulates to the effect that I abandoned the Difference Engine in order to proceed with the Analytical Engine. That is entirely false as you know. The Chancellor of the Exchequer himself gave the true reason, namely, expense. Nor did I quarrel with Clement as some have suggested. I considered his demands to be exorbitant, but I never said or wrote an unkind word to him.

Henry: It was shortly after I arrived in England that Mr. Sheepshanks published his infamous pamphlet.

Babbage: As long as such charges are confined to the Reverend Richar Sheepshanks' pamphlet, they have no effect. It is a different matter when they appear in the public print. I had recently to write to the Morning Chronicle denying a report that had appeared in that paper.

Henry: I met Mr. Sheepshanks, you will remember, at Greenwich. You took me with you on the Admiralty barge when you went to attend a meeting of the Visitors.

Babbage: What impression did you form of him?

Henry: Oh, he was agreeable enough.

Babbage: He can be on social occasions. I was unfortunate to be opposed to him in the arbitration concerning the Equatorial Telescope made by Troughton for Sir James South.

Henry: That must have been a disagreeable case for you to be involved in.

Babbage: It was. I had at first refused to be a witness on behalf of Sir James. However, the late Lord Abinger repre sented to me that my evidence was necessary to the justice of the case. Otherwise, I would have persisted in my refusal.

Henry: Mr. Sheepshanks was a witness on the other side?

Babbage: He was more than that. He had studied the law after taking his degree at Cambridge. It was curious to see the energy and vigour with which he applied himself to the exercise of his youthful studies.

Henry: You mean he took charge of the case for Troughton?

Babbage: He did. But that is not all. After I had given my evidence—but before I had been cross-examined on it—he took occasion to say that because I supported Sir James, I must be discredited. He went on to threaten to attack me publicly on another subject at a future time.

Henry: That sounds like tampering with the witness.

Babbage: Exactly. I felt that it would be unsafe for the cause of justice—and possibly injurious to myself—if I did not take measures for making known the nature of the weapons that the Reverend Richard Sheepshanks was employing.

Henry: That was why you denounced him in your book.

Babbage: Yes. His pamphlet was his reply.

Henry: I can understand his wanting to make a reply, but I think he went rather far in his personal attack on you.

Babbage: Let my detractors say what they will. If I survive some years longer, the Analytical Engine will exist, and its works will be spread over the world. Soon copies will be made, and there will be an Analytical Engine in every capital. They will be in constant employ for investigations in which profound analysis is necessary.

Henry: Yes. I realize that calculating machines are not for doing ordinary sums in arithmetic—nor for use by vendors of vegetables and little fishes—as Leibnitz put it. But what would you say are the limits of the Analytical Engine viewed as an automaton?

Babbage: The Analytical Engine itself is confined to calculation. But the same principles could be used to construct automata for other purposes.

Henry: Games of skill, for example.

Babbage: Yes. At one time I gave much thought to that subject for its philosophical interest.

Henry: We have talked about tit-tat-to, or noughts and crosses, as it is called.

Babbage: That is the simplest of such games. It is easy to make a machine to play it and always to win, when winning is possible under the rules.

Henry: In a game like chess, however, the number of combinations is enormously greater, and foresight is required.

Babbage: That is so. But I have, after all, devised for the Analytical Engine means equivalent to foresight, and even allowing a hundred moves for a game of chess, the number of combinations available in the Analytical Engine greatly exceeds what is required. I believe that the principle on which the Analytical Engine is based would allow the construction of an automaton capable of playing chess.

Henry: Perhaps such an automaton will one day be built.

Babbage: Possibly, but it is hard to see why anyone should want to do so. There would be little profit in it. I am told that even the machine for writing Latin verses was an entire failure from a pecuniary point of view. The most profitable exhibition which has occurred for many years is that of General Tom Thumb, the American midget.

Henry: We are truly fortunate to live in a time of such progress: steamships, railways, the electric telegraph . . .

Babbage: I would gladly give up the remainder of my life if I could come back for three days in a hundred years' time and have some competent person explain to me the discoveries that had been made.

Henry: I am about to make a journey back into the past. India so far has hardly felt the march of progress.

Babbage: That will come.

Henry: (Looking at his watch) I think I should say good night now, Sir. My furlough has been profitable to me in many ways. Not least has been the privilege of being present when the Analytical Engine was coming into being.

Babbage: My fear is that I shall be called to my account before I have accomplished my plan.

There is no self-importance, no illusions about him now, as he speaks, half to Henry, half to himself, the simple truth.

Babbage: It must be that one day some person will succeed in doing what I have set out to do. He may employ different mechanical means. He may call his machine by some different name. But he and he alone will be capable of appreciating the nature of my efforts and the value of their results. I shall have no fear of leaving my reputation in his hands.

Henry: You can be sure of having the acclaim of posterity, Sir. I pray that you may be spared long enough to receive it in your lifetime. Good night.

Babbage: Good night, Henry.

Henry goes out. Babbage pauses for a moment and then goes over to his writing table and begins to spread out his papers. He is just sitting down when a thought strikes him. He goes out and shortly returns carrying a looking-glass which he puts back in its old place on the wall. He then settles to work.

THE END

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The Computer Museum Bits and Bites

Bits of history and bites for sustenance

Nine Sunday Afternoons

At 2 pm, guided tours covering highpoints of the Museum

AT 3 PM . . .

September 18
3 pm

Kurzweil Reading Machine, a reader for the blind demonstrated by its engineers.

"The greatest thing since Braille." Kurzweil's Reading Machine reads printed material aloud. An electronic scanner with a speech synthesizer, it can identify 200 different typefaces and is programmed with 1000 linguistic rules and 2000 exceptions.

September 25
3 pm

Joseph Hammond on the Evolution of Multiwire Technology and Its Impact on Computer Packaging

In 1966, Hammond and others designed the first machine to automatically wire printed circuit boards. It and subsequent multiwire wiring machines have dramatically altered computer packaging.

October 2
1–5 pm

The Computer Museum Yard Sale

Overstock memories, disk drives, consoles and even computers from the Museum's collection will be for sale. Cash and carry only; no deliveries. Browsers welcome.

October 9
3 pm

R. Michael Hord on the Illiac IV

Illiac IV, displayed in the Museum's supercomputer gallery, was the biggest and fastest machine of its time—a 96 ton giant capable of 300 million operations per second. Hord is author of *Illiac IV, The First Supercomputer.*

October 16
3 pm

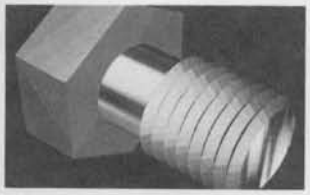
Perry Crawford on Vannevar Bush and the Whirlwind

Bush's differential analyzer provided the inspiration for the Whirlwind, and Crawford followed the evolution of both at MIT.

October 23
3 pm

Robert V. D. Campbell on the Harvard Mark I–IV

A multi-media presentation on these revolutionary computers designed at Harvard presented by Campbell, one of the designers involved with the project from the Mark I on.



October 30
3 pm

Andries Van Dam presents a Graphical History of Computer Graphics

The progress of interactive computer graphics explored through film and video clips by van Dam, author of Fundamentals of *Interactive Computer Graphics.*

November 6
3 pm

Mike Kryskow on the Development of Telecommunications

A telecommunications engineer, Kryskow will explore the phenomenal growth of networks. Telecommunications networks now link continents, cities and businesses, simplifying everything from banking to weather reporting.

November 13
3 pm

Jack Dennis and John McKenzie on the TX-0 in Action

An inside perspective and demonstration of the TX-0, the first full-scale transistorized computer and a Computer Museum exhibit. McKenzie and Dennis worked on the TX-0 and its expansion during its 18-year reign at MIT from 1956 to 1974.

THE END BIT 0000000000000001

A newsbrief of the collection

While driving home from work one evening in the fall of 1966, R. Page Burr (now a senior scientific officer at Kollmorgen Corporation) envisioned a way to improve interconnections on printed circuit boards. Connections were originally made by hand placing and soldering discrete wires. Mr. Burr's improvement consisted of copper lined holes interconnected by insulated wires. Interconnection devices of almost any complexity could be made because the insulated wires would be able to cross.

Mr. Burr's idea evolved into the Multiwire Wiring Machine. Pictured is the tacking head from the first production wiring machine, a donation to The Computer Museum by PCK Technology, a division of Kollmorgen Corporation.

The
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