THE COMPUTER MUSEUM REPORT

FALL/1982

VACUUM TUBE POWER DRIVER FOR THE FIRST CORE MEMORY, WHIRLWIND COMPUTER, 1951. INTEGRATED CIRCUIT MODULE PROTOTYPE, APOLLO GUIDANCE COMPUTER, 1965.

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Cover photo of vacuum-tube power driver of the first core memory of Whirlwind, 1953, and integrated circuit module prototype, Apollo Guidance Computer, 1965 by Clint Clemens. The photo is available as a full color poster (20 × 30 inches) $4.00.

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

The Computer Museum Report is published quarterly by The Computer Museum, One Iron Way, Marlboro, MA 01752. Annual subscription is part of the membership of the Museum ($25 per year for individuals and nonprofit organizations and $125 for corporations).

The purpose is to report on the programs and exhibitions of the Museum. The contents of The Computer Museum Report may not be reproduced without written consent.

The Museum Staff is responsible for the contents of the Report. The opinions expressed do not necessarily represent those of The Computer Museum or its Board of Directors.

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

The Computer Museum
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Since computer history is only now being written, the policy of the Museum is to develop evolving exhibitions. Thus, our galleries represent working drafts, allowing visitors to see the collections while we continue to supplement and revise them.

The Pioneer Computer Timeline was opened in October 1981. After it opened, artifacts that no one knew existed were unearthed. For example, Toby Harper, who worked on code-breaking at Bletchley Park, saw the Colossus photographs and remembered that he had one of the pieces from its tape feeding mechanism. He was going to use it as a telescope base that was never made.

Our display of Super Computers is especially dynamic. The collection of early machines is continuing, while we keep in mind today's computers that will be retired in the future. George Michael of Lawrence Livermore Laboratory, responsible for the donation of the CDC 6600 #1, is shown with Jamie Parker, Exhibit Coordinator, discussing the Cray I and future plans for the Super Computer exhibit.

The newest gallery, the Four Computer Generations, is organized to show the new inventions, first machines, new corporations, representative languages and applications characteristic of each period. After he saw the exhibition, Lester Hogan, one of the members of the Museum's Board of Directors, wrote a long letter with the following suggestions:

> "I was particularly pleased with the handling of the history of 'the chip' by starting at Bell Labs and then mentioning the contributions of Dummer, Kilby and Noyce. I do, however, think it is important to emphasize the fact that dozens of researchers recognized that semiconductors offered the possibility of many transistors on a single chip and there was much more activity going on in various labs trying to find a really good method of building such a device than most people realize. In 1953, when a patent was issued to Syd Darlington, the general attitude at Bell Labs was that Syd was right and that this would happen someday but that it had to wait until we had a better way to make transistors. The alloy junction was indeed a better way and when it became a reality, Harwick Johnson at RCA Princeton took the concept even further and built a phase shift oscillator. Again, the general response was, 'Well, this is a lot better but it still isn't right.' Then Kilby took the concept of the diffused base mesa transistor even further. I remember my reaction was, 'Well, it's closer, but it still won't fly.' Then came Bob Noyce's suggestion using the planar process and we all ran very fast to bring that one process to reality."

The exhibition will be changed to reflect this evolutionary development.

As each exhibition nears stability, catalogs, slide sets, and other materials useful for reference and teaching will be produced to better serve our far-flung audience.

Gwen Bell
Director

The Apollo Guidance Computer
A Designer's View

Eldon Hall *Designer, Apollo Guidance Computer*

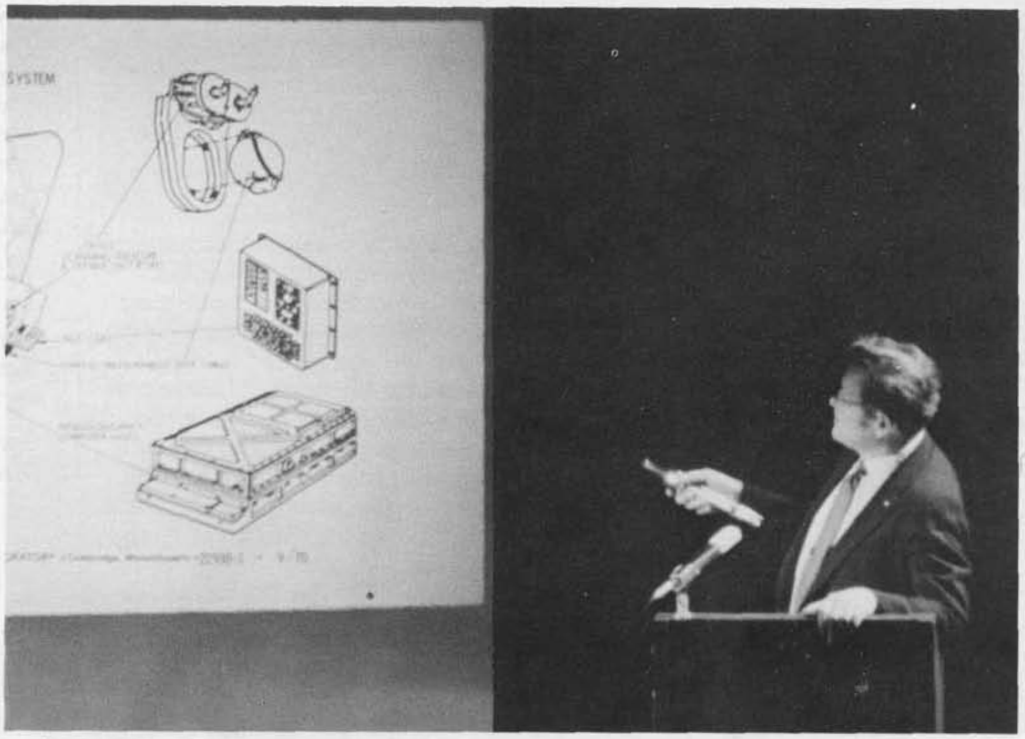
In the early sixties the so called mini-computer had not emerged and there was no commercial computer suitable for use in the Apollo mission. Most of the technologies that were eventually used in the Apollo computer were just emerging from research and development efforts. The design was mainly a task of fitting the components together in order to meet the mission requirements for computational capacity and miniaturization.

From Polaris to Apollo

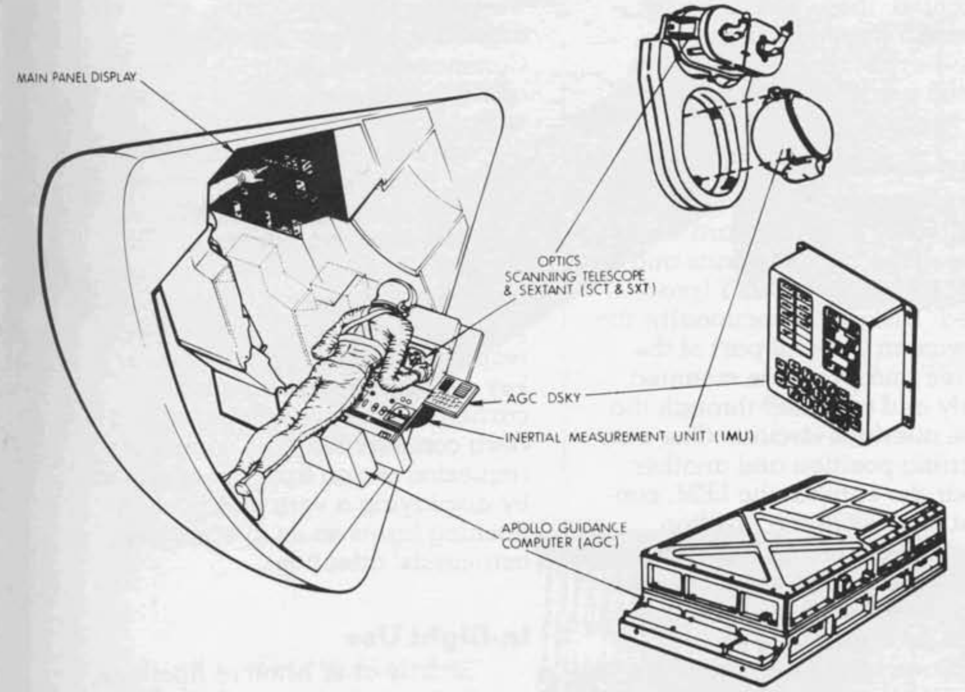
Previous aerospace computers greatly influenced the development of the Apollo Guidance Computer. The demands that were placed on these computers provided the motivation to miniaturize and develop semiconductors. The MIT Instrumentation Lab, now called Charles Stark Draper Laboratory, had the responsibility for the design of the computers used in the Polaris, Poseidon, and Apollo programs.

The lab's first significant venture into the field of digital computing was for Polaris, a very small ballistic missile launched from a submarine. A special purpose digital computer was designed to solve the specific equations required for the guidance and control system based on analog techniques originally developed by the Navy. With the need for increased accuracy the Navy decided to use digital techniques for the Polaris program, resulting in the construction of a wired-program special purpose computer to solve the guidance and control equations. In 1959 the first version of this system, called the Mark 1, flew in a Polaris missile. It was the first guided flight of a ballistic missile flown with an on board digital computer providing the guidance and control computations. The computer occupied about four-tenths of a cubic foot, weighed 26 pounds, and consumed 80 watts. Even before this first guided flight designs were being explored which would reduce the size and improve the maintainability of the system. The new design, eventually designated Mark 2, repeated the architecture and logic design with improvements in circuits and packaging.

In August 1961, when NASA contracted the laboratory to develop the Apollo guidance, navigation, and control system, the mission and its hardware was defined in only very broad terms. A general purpose digital computer would be required to handle the data and computational needs of the spacecraft. Therefore a special arrangement of display and controls would be necessary for in-flight operations.



Eldon Hall pointing to one of the many diagrams shown during his illustrated lecture.



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Major units of the CM Guidance, Navigation and Control System.

The boost phase of the mission, which was the Saturn system, had its own internal guidance system to put the command and service module in translunar trajectory. Then the Apollo system took over to guide the mission to the moon.

In effect, navigating in space is the same as navigating on Earth. One might take a star sighting with a sextant. That information is put into the computer and from it the state vector, i.e. the position and velocity of the missile at any point of time, is computed. The computer orients the missile such that the change in velocity will cause the state vector to be updated so the missile will free-fall into the targeted point. While it is thrusting, the guidance system must control the attitude of the vehicle, the magnitude of the thrust in the case of the Lunar Excursion Module (LEM), and the direction of the thrust in the case of the Command and Service module.

Design Constraints

Initially, the need for a very reliable computer with significant computational capacity and speed was clear. The design constraints included very limited size, weight, and power consumption. If the designers had known then what they learned later, or had a complete set of specifications been available as might be expected in today's environment, they would probably have concluded that there was no solution with the technology of the early sixties.

Establishing interface requirements was a monumental task. The astronaut interface was one of these. In 1962, computers were not considered user friendly. Heated debates arose over the nature of the computer displays. One faction, which usually included the astronauts, argued that meters and dials were necessary. Logically, the pressure for digital displays won most of the arguments because of their greater flexibility in the limited area allowed for a control panel. In late 1963, as the requirements for the LEM were being firmed up, NASA decided to use identical guidance computers in both the command module and the LEM.

In the early manned orbital missions before Apollo, NASA learned that the human animal, confined in a spacecraft for a week or so, was not as clean as might be expected from observations on Earth. This additional constraint had a rather interesting and far-reaching impact on the mechanical design of the computers and other hardware. All electrical connections and metallic surfaces had to be corrosive resistant and even though the computer was designed to have pluggable modules, everything had to be hermetically sealed.

The Suppliers

By the end of 1962, NASA selected three contractors: General Motors' AC Sparkplug Division for the inertial systems and system integration; Raytheon, Sudbury Division, for the computer and computer testing equipment; Kollsman Instrument for the optical systems; North American Aviation for the command and service module; and Grumman Aircraft for the Lunar Excursion Module.

In late 1959 and 1960 the lab began evaluating semiconductors, purchased at $1,000 each from Texas Instruments. Reliability, power consumption, noise generation, and noise susceptibility were the prime subjects of concern in the use of integrated circuits in the AGC. The performance of these units under evaluation was sufficient to justify their exclusive use in place of the core transistor logic proposed initially for the Apollo project design. The micrologic version of the Apollo computer was constructed and tested in mid 1962 to discover the problems that the circuits might exhibit when used in large numbers. Finally, in 1964 Philco-Ford was chosen to supply the integrated circuits used in the prototype computer that operated in February 1965. These cost approximately $25 each.

Specifications

Approximately one cubic foot had been allocated in the command module for the computer. The first prototype was operating in the spring of 1964 and utilized the wire wrap and modular welded cordwood construction which had been produced for the Polaris program. It was designed to have pluggable trays with room for spare trays.

Since the clock in the computer was the prime source of time, it had to be accurate to within a few parts per million. The data and instruction words in the memory were 15 bits plus parity. Data was represented as 14-bit binary words plus the sign bit. Double precision operations were provided to supply 28-bit computations. The instruction word contained the address and operation codes for the computer operation. The memory address field was extended by organizing the memory in banks.

The AGC had 2,000 15-bit words of erasable core memory and started with 12,000 words of read-only memory, called rope memory. It was quickly upgraded to 24,000 words. Then by mid-1964, when the first mission program requirements had been conceived and documented, there was increasing concern about the possible insufficiency of the memory. This prompted a further expansion to 36,000 words.

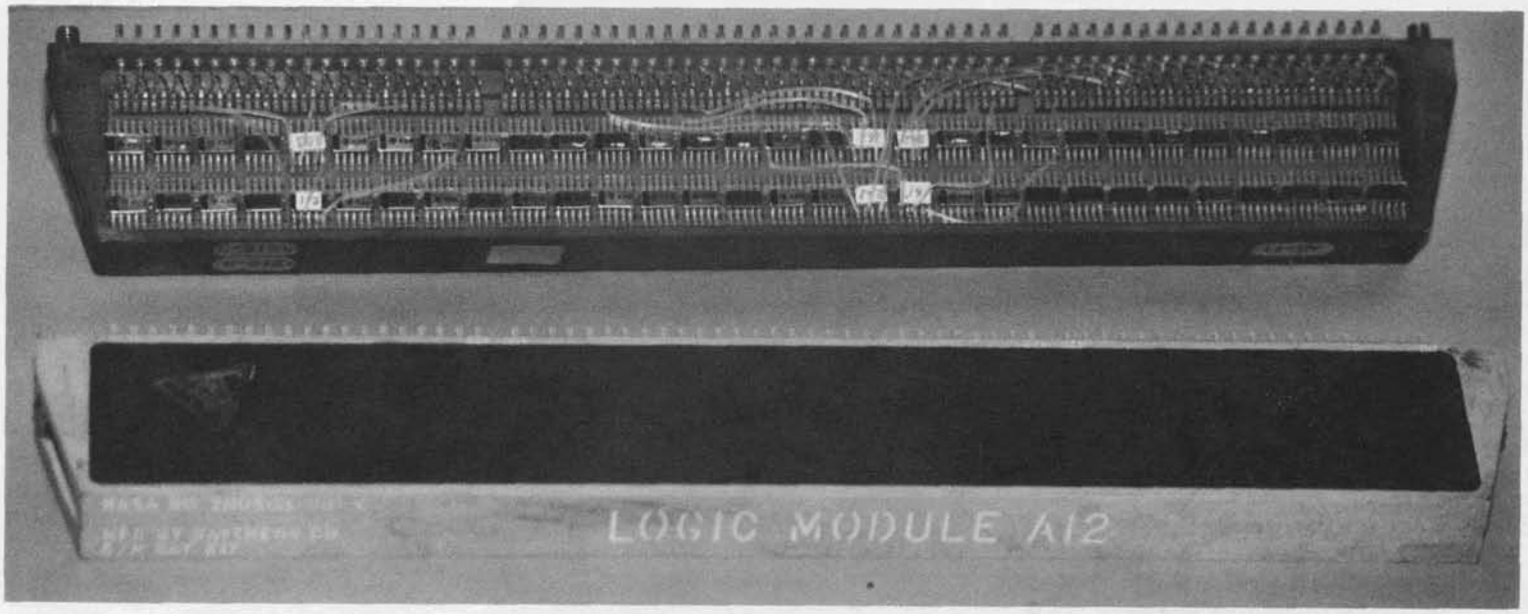
Design and Use of the Console

A display and keyboard was developed for the astronauts and had the designation DSKY (pronounced "Diskey"). Functionally, the DSKY was an integral part of the computer, and two were mounted remotely and operated through the discrete interface circuits. One was for a sitting position and another one near the entry to the LEM, convenient for a reclining position.

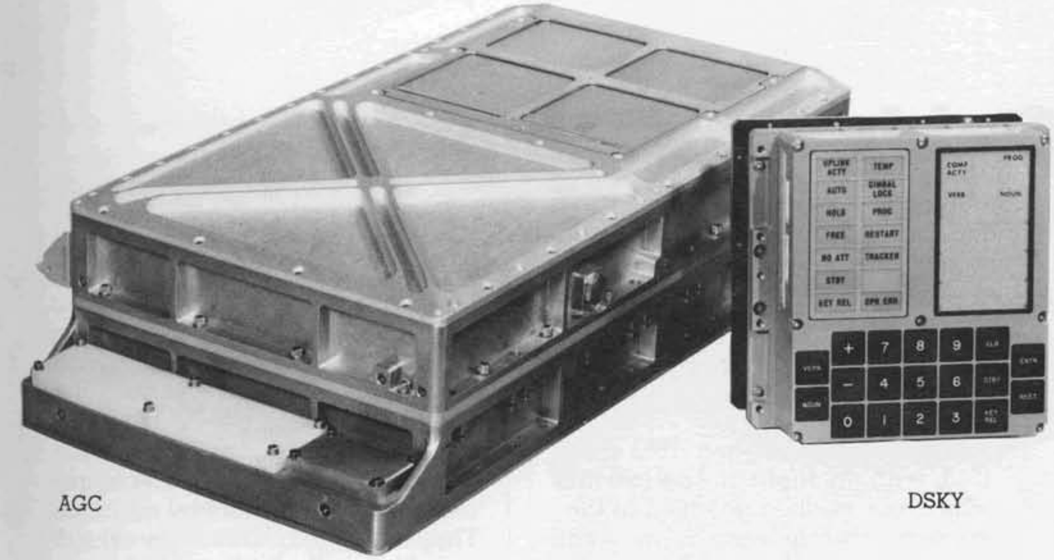
The principle part of the DSKY display was a set of three numeric light registers. Each register contained 5 decimal digits consisting of segmented electroluminescent lights. Five decimal digits were used so that a computer word of 15 bits could be displayed in either decimal or octal. In addition, three two-digit numeric displays indicated the major program in progress, the verb code and the noun code. The verb/noun format permitted communication in a language whose syntax was similar to that of spoken language. Examples of verbs were display, monitor, load, and proceed. Examples of nouns were time, gimbal angles, error indications, and star identifications. Commands and requests were made in a form of sentences, each with a noun and a verb, such as display velocity or load desired angle. To command the computer the operator pressed the Verb key followed by a two digit code. This entered the desired verb into the computer. The operator then pressed the Noun key and a corresponding code. When the enter key was pressed, the computer carried out the operation that had been commanded. The computer requested action from the operator by displaying a verb and noun in flashing lights so as to attract the astronauts' attention.

In-flight Use

Shortly after liftoff of Apollo 12, two lightning bolts struck the spacecraft. The current passed through the command module and induced temporary power failure in the fuel cells supplying power to the AGC. During the incident the voltage fail circuits in the computer detected a series of power trenches and triggered several restarts. The computer withstood these without interruption of the mission programs or loss of data.



The module in the background is exactly the same as one in the foreground, but it has only been used on Earth. The Museum's prototype computer ran at Draper Labs and was used to test the routines for the in-flight machines. In space all of the components had to be totally "potted" to insure that all the parts would stay firmly in place and remain uncontaminated during space flight.



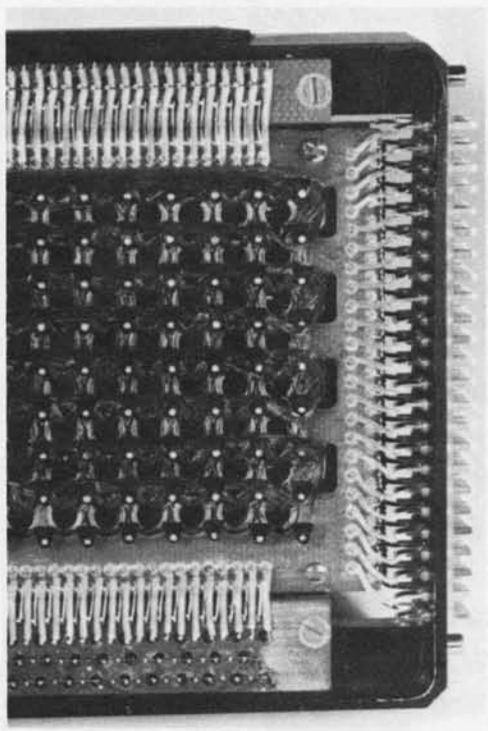
AGC

DSKY

The Apollo Guidance Computer, shown on the left, was responsible for the guidance, navigation, and control computations in the Apollo space program. The AGC was the first computer to use an integrated circuit logic and occupied less than 1 cubic foot of the spacecraft. It stored data in 15 bit words plus a parity bit and had a memory cycle time of 11.7 microseconds, utilizing 2,000 words of erasable core memory and 36,000 words of read-only memory. The frame is made of magnesium for lightness and designed to hermetically seal the components.

The interface with the astronauts was the DSKY, shown on the right. It used digital displays and communicated with the astronauts using the verb and noun buttons visible in the photograph and two digit operation and operand codes. A set of status and caution lights is shown in the top left corner of the DSKY.

The AGC and DSKY are on display in the Four Generation Gallery.



The AGC rope memory

The read-only memory of the computer consisted of six rope memory modules, each containing 6,000 words of memory. This special type of core memory depended on the patterns set at the time of manufacture. Its sensing wires were woven into a set pattern information. It had five times the density and was far more reliable than the coincident current core memory used for erasable storage in the computer. Being unalterable, it also provided a greater incentive for error-free software development.

The AGC rope memory is on display in the primary memory case.

The Apollo 11 lunar landing had an anomaly which attracted public attention. The computer in the LEM signalled a restart alarm condition several times during a very critical period prior to touchdown. This fact was broadcast to the public and those who knew its significance were close to a state of panic. After analysis, it was determined that the alarms were an indication to the astronauts that the computer was overloaded and was eliminating low priority tasks from the waitlist.

The overload resulted from the rendezvous radar being set in the wrong mode during the lunar landing phase, wasting computer memory cycles. The computer software was responding to overloads as designed.

This incident triggered a news brief in Datamation in October, 1969, faulting the computer design for being too slow. It rightfully claimed that there were a number of minicomputers, including the PDP-11, that were at least an order of magnitude faster. In the eight years since the initiation of the Apollo program commercial technology had far surpassed that of the Apollo design and capacity. However, no commercial computer could claim to match the power consumption and space characteristics of the AGC.

Excerpted from an Illustrated Lecture, June 10, 1982, by Ben Goldberg. The video-tape is archived by The Computer Museum.

The Apollo Guidance Computer
A Users View

David Scott *Astronaut for the Gemini 8, Apollo 9, and Apollo 15 missions.*

In 1963 when NASA was conducting the selection of the third group of astronauts for the U.S. space program, I had just received a graduate degree at MIT and finished test pilots school. My interests and the program's need for a user to interact with the design of the guidance computer at the MIT Instrumentation Lab was a good fit. I was part of those discussions whether to use analog or digital controls that Eldon described.

The MIT Interface

When I was studying at MIT, the ability to rendezvous in space was an issue for debate. It wasn't clear whether it was possible to develop the mathematics and speed of computation necessary to bring two vehicles together at a precise point in space and time—a critical issue for the Apollo missions successful landing on the moon and return to Earth. Between 1963 and 1969, with the flight of Apollo 9 this was accomplished. I stayed in the spacecraft while Rusty Schweickart and Jim McDivitt got in the lunar module and went out about 60 miles away. The computer behaved flawlessly during our first successful rendezvous in space.

Another assignment for Apollo 9 was to take the first infra-red photographs of the Earth from space. To do this, a large rack of four cameras was mounted on the spacecraft. Since they were fixed to the spacecraft, the vehicle itself had to track a perfect orbit such that the cameras were precisely vertical with respect to the surface that they were photographing. During simulations it was determined that manual orbit procedures would be inaccurate. We were at a loss. About two weeks before the flight I called up MIT and asked if they could program the computer to give the vehicle a satisfactory orbit rate. They answered, "Of course, which way do you want to go and how fast?". In a matter of a couple of days we had a program and a simulator that automatically drove a spacecraft at perfect orbit rate. We got into flight with very little chance to practice or verify, but we put on the cameras and the results were perfect.

Potential Computer Failure

During the development process we ran many simulations of in-flight computer operations with particular concern for in-flight failure. But in the 10 years that I spent in the program there was never a real computer failure. Yet, people often wonder what a computer failure would have meant on a mis-

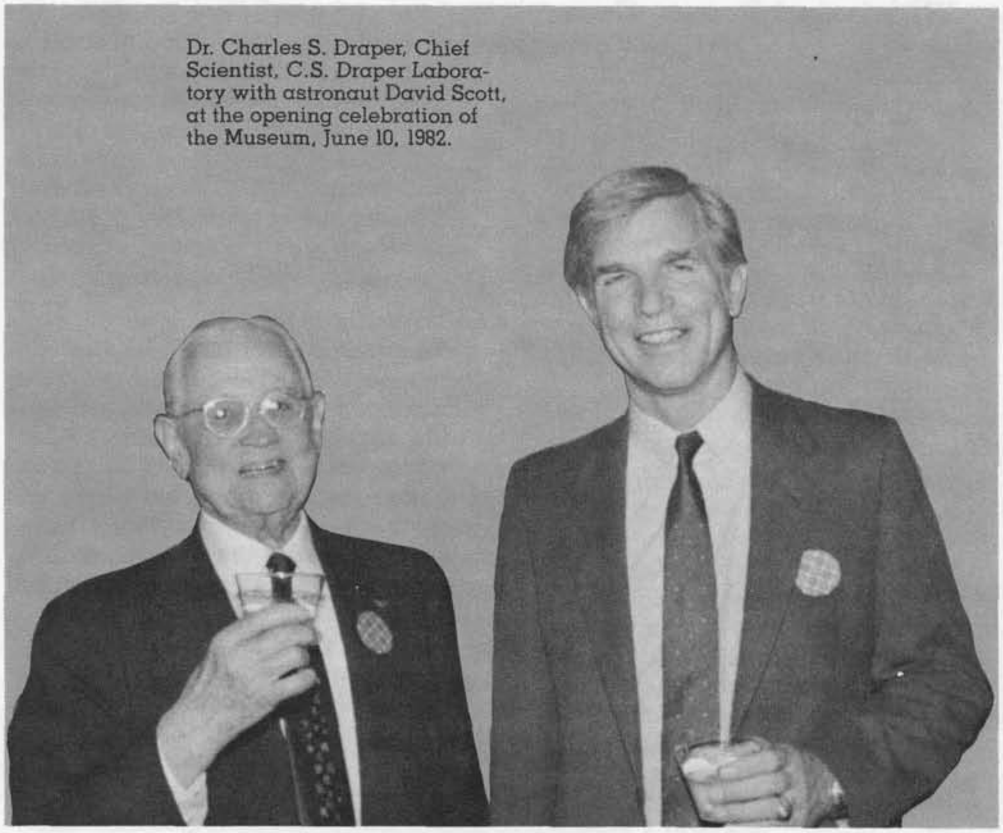
sion. It would have depended on the situation and the manner in which the computer failed. We probably would not have expired, but there were some parts of the mission in which a computer failure would have been especially compromising. Navigation was not necessarily time critical but the lunar landing was very time critical. You could have a situation during a lunar landing in which, if the computer failed, the engine would be driven into the ground. Unless the astronaut could react quickly enough to stop it, the Lunar Module could have been flung on its side. Chances are that the astronaut could prevent such an event by switching to manual control of the vehicle. It must be remembered that the computer had been designed to be as reliable as possible and the astronauts had a great amount of confidence in the machine.

And Problems of Success

We had a backup called the entry monitor system, which had a graphic display based on the accelerometers in the spacecraft. With this display the vehicle could be flown manually using pre-drawn curves to be followed for attitude, g-loading, and velocity. It was reassuring to know that we were still able to return to Earth even if the Apollo Guidance Computer failed. During reentry there was a scroll in the entry monitor system and we could see the computer tracking the predetermined curves all the way to the landing site. As our skills and the computer programs improved over the years of the Apollo program, we came down closer and closer to the carrier. Finally, by the last Apollo mission they didn't park the carrier on the landing point.

Excerpted by Ben Goldberg from remarks after Eldon Hall's Lecture, June 10, 1982.

The Apollo 9 Crew, (from left) Dave Scott, Command Module Pilot; Jim McDivitt, Commander; Rusty Schweickart, Lunar Module Pilot. Apollo 9 was launched on March 3, 1969. The first separation and rendezvous of the Lunar and Command Modules was carried out in Earth Orbit on this flight.



Dr. Charles S. Draper, Chief Scientist, C.S. Draper Laboratory with astronaut David Scott, at the opening celebration of the Museum, June 10, 1982.

"Before the missile and Apollo guidance programs, the problem of airplanes attacking ships at sea was a difficult one, so I began to do the ballistics analysis myself, plotting on a sheet with a pencil and a slide rule. This analysis worked well enough so that ships were able to defend themselves against air attacks. When the time came to develop the Polaris and Apollo programs, our attitude was much the same: we couldn't afford any failures, so we didn't have any."

Dr. Draper at the lecture on the design of the Apollo Guidance Computer.

Whirlwind Before Core

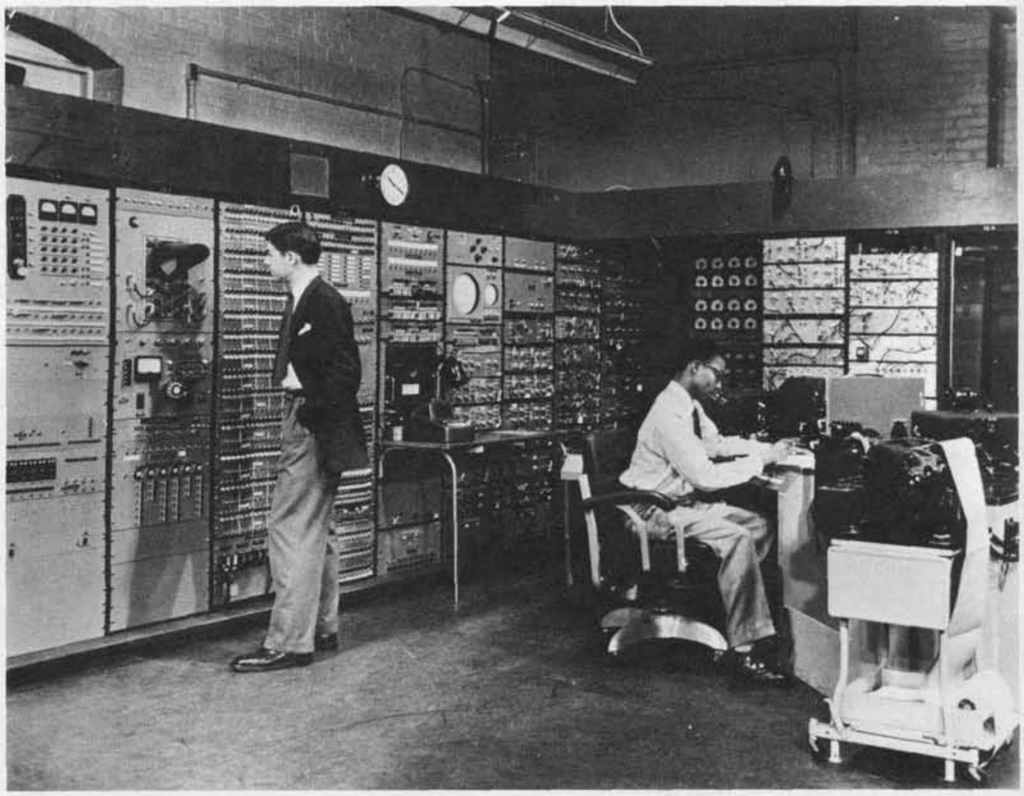
Reminiscences of Jack Gilmore

In October, 1950, I joined the Whirlwind team. At that time the first thirty-two registers of toggle switch memory were working. The four variable flip-flop registers could be assigned to any one of the thirty-two addresses. They were able to demonstrate small mathematical programs such as the bouncing ball problem or solve simple differential equations. The first memory consisted of electrostatic storage tubes totaling 256 locations. We felt really rich with a full 256 variable registers to write our programs. We calculated the operation in the octal address and then looked up what was then called the sexidecimal conversion number (later the term hexadecimal was used). We had a little load program in the 32 registers and that bootstrapped the programs up into the memory in order to run them.

The first thing that we were very anxious to do was to get an assembly program that would allow us to be able to write our programs using mnemonic symbols and expressing the numbers in decimal and octal. My boss, Charlie Adams, was concerning himself with that and so it became my job to write the assembly program. I'm fairly certain that if it is not the first, it is one of the very first assembly programs ever written. The only one that I know of that predates it was Wilkes' 'Load and Go' on the EDSAC.

In September, 1951, John Carr, later Chairman of Duke's Computer Science Department, and I wrote a document that explained how people could actually use subroutines in conjunction with assembly programs, so that they didn't have to write all the various utilities. People could write their programs in a relative fashion and then we would give them the library of subroutines and they'd actually pick out the tapes that they needed. We'd then string the tapes together and literally make a copy not only of their program but also of the subroutines. All of those would be pulled in through the bootstrap program and it would run. This was the indirect birth of the symbolic address. The thing that we discovered, I think I actually discovered it, was that when we ran the tape through twice, you could refer to an address above where you were, as opposed to everything going below. The two pass assembler came out of all that. I have a recollection of Charlie Adams and I briefing IBM's Nat Rochester on how to produce symbolic addresses.

The Ph.D. candidates who needed to use the Whirlwind really didn't know how to run the machine. There were full scale electronic technicians who knew how to bring it up, and most of the systems programmers like myself knew how to do it, as well as some of the engineers. It was a fairly routine procedure so I went to Charlie Adams and suggested that I could train two people right out of high school to be computer operators if I had enough funds to hire them for one year. Jay Forrester provided the funds and I went out to two local high schools and asked for students that were college material but didn't have the money for college. I hired Joe Thompson from Boston Technical High School (shown sitting down in the photograph) and Bill Kyle from Boston English. Within four or five months they were competent operators, and Joe stayed on to complete his



This 1951 photograph of Whirlwind shows Joe Thompson seated at the Flexowriter typewriting unit. Jack Gilmore is standing in front of the 256 × 256 point display used for alphanumeric and graphic representations of various computations. The display was utilized to plot solutions of partial differential equations for determining the optimal rate of pumping oil from underground caverns and also for displaying the optimal placement of television antennas for compliance with F.C.C. regulations.

degree at Lowell Tech in the evenings. One day Forrester came in and sat at the back of the room. He watched for about an hour while Bill and Joe completed eight or nine different jobs. Finally Jay said, "We've just created a new vocation." He also recognized this as the solution to the problem of computer operators for the SAGE project.

The flexowriter typewriting unit we used was a word processing system, originally designed for list processing and promotional mailings. It had a mechanical reader and would create a form letter in a loop with stop codes to key in the personal information. We used it as an integrated word processing system, circa 1951.

One Sunday afternoon in December 1951 the Whirlwind was featured on 'See It Now', Edward R. Murrow's program. Ron Meyer and I stayed up all weekend writing a program to display the trajectory of a Viking rocket on the display and another program that played Jingle Bells. They wired Jay Forrester with a mike and had the wire coming up his back with cables on the floor so he could walk from one part of the console to another. As he started to walk the wire snagged and the back of his coat started to come up. One of the CBS technicians decided that he was going to undo the snag and started to crawl across the floor like a commando. Forrester, not realizing that his coattails were at 90 degrees, couldn't understand why the technician was crawling towards him. We decided that Forrester was getting too distracted and so the technician was pulled back across the floor by his ankles. Meanwhile, Edward R. Murrow and Jay Forrester completed the interview which ended with Jingle Bells being played for the pre-Christmas viewers.

[The museum has archived a copy of the video tape of the Murrow interview in which Jack Gilmore may be seen loading the tape reader]

Extracted by Ben Goldberg from a Gallery Talk by Jack Gilmore, June 16, 1982.

Profile of a Board Member

Les Hogan's involvement in electronics began while he was in the Navy during World War II. His work with the acoustic torpedo led him to obtain a doctorate in physics at Lehigh following the war. In 1950, three months after he joined Bell Labs, he invented the microwave gyrator. In 1953, he was invited by John VanVleck to become a Professor at Harvard University.

Hogan's influence on the development of the semi-conductor began in December 1957, when he became executive vice-president of Motorola and general manager of the semi-conductor division. He later became President and Chief Executive Officer of Fairchild Camera and Instrument. At present, Dr. Hogan spends about half his time as Technical Advisor to the President of Fairchild, is an active board member of six corporations, and is advisor to Stanford, Berkeley, and MIT's engineering schools.

Dr. Hogan is deeply interested in the development of The Computer Museum because, in his words, "I have spent my entire career in high technology electronics including the last twenty-five years working on the semi-conductor. Computer technology has been my life."

Reported by Allison Stelling.

"All of the memorabilia in junk piles across the country needs to be collected so that people can see what the early days of computing looked like. With such fast-changing technology, a computer museum is as much for the people who are part of the industry as it is for the next generation."

C. Lester Hogan

Opening Celebration: June 10th 1982

The Board of Directors and the Chairman of the Members' Association switched on the breadboard of the Atanasoff-Berry Computer, ceremonially "turning on" the Museum. George Michael and Gwen Bell wait to flip a switch on the Atanasoff-Berry breadboard. Kitty Selfridge is at the control panel, while Michael Spock, Lester Hogan, Gordon Bell and Brian Randell watch.

At the Opening and first board meeting, many of the Board members had their first tour of the Museum. The old hands, such as Gordon Bell, each had their assignment to explain and guide a new board member through the exhibitions. Gordon is giving Senator Paul Tsongas and his aide Andy Bagley an overview using the self-guiding brochure now available.

ARCHIVES AND LIBRARY

This fall, Gregor Trinkaus-Randall will join the staff as archivist and librarian. Gregor will work to establish an archives and library for scholarly use.

An Archives Advisory Committee met for the first time on June 9 and will meet again in May of 1983. Committee members will assist Gregor in the development of a comprehensive computing history archives. Those interested in participating should contact Gregor Trinkaus-Randall at the Museum.

The Library and Archives will be located on the lobby floor of the Museum and should be open in the spring of 1983. The collection will include documents relevant to exhibited artifacts. With only a small budget for acquisitions, the Library and Archives will be dependent upon donations of deaccessioned materials from company and private libraries.

INTERN PROGRAM

This summer, eight interns worked at the Museum on various special projects. Students are invited to apply for paid internships at the Museum for any period up to six months. The number of students will vary according to the number of activities going on at any time. Internships will complement the various operational sections of the Museum. The listing of this summer's interns and their activities indicates the wide range of possibilities.

Beth Parkhurst started as an intern in the summer of 1981. She is now a Research Assistant at the Museum, spending one day a week during the school year while she works to complete her Ph.D. in the American Civilization program at Brown University.

Andy Kristoffy, a junior in Computer Science at the University of Massachusetts, will spend next year at the University of Manchester. Andy also started in 1981 and this summer has assisted Jamie Parker in the organization and installation of the Four Computer Generations exhibition.

Ben Goldberg recently completed his B.A. at Williams and is entering the Ph.D. program in Computer Science at Yale University. Ben prepared the story of the Apollo Guidance Computer in this issue and will work on a comprehensive exhibit of the Polaris and Apollo Guidance Computers.

David Bromfield, a Senior at MIT in Business Management, is the Acting Business Manager. As such, he has set up the initial accounting systems for the Museum.

Roberto Canepa, a junior in electrical engineering at Carnegie Mellon University, has been rebuilding the number sieves built by Professor Derek Lehmer of Berkeley. His two biggest challenges are the recreation of a bicycle chain machine from photographs taken in the 1920s and the restoration of the gear machine exhibited at the 1932 Chicago World's Fair.

Allison Stelling, a junior at Harvard majoring in History and Computer Science, has concentrated on doing research to gather photographs for our collection.

Beth Parkhurst showing Uta Merzbach, Curator of Mathematics at the Smithsonian, the Four Generation Gallery.

Farrell Woods, a sophomore at the University of Massachusetts, has organized the Museum's artifact storeroom. He is drafting a proposal for the development of a build-your-own tinker-toy computer.

Gayle Morrison, who will enter Becker Jr. College in the fall, plans to major in Word Processing Administration. She has assisted Sue Hunt, the Museum's main secretary, with all the extra activities.

SUMMER GALLERY TALKS

The summer gallery talks provided informal seminars on computer history for visitors, summer interns, and staff. As part of our archival efforts, each intern was given the responsibility for audio taping and transcribing one talk, and, if appropriate prepare it as an article for the *Report*.

These talks provided a focus for the week and will be repeated next summer—perhaps with even greater frequency. We have all found that many of the Museum's members and visitors have a great deal to add to our knowledge and so we invite self-nominations for giving a gallery talk.

June 16. Jack Gilmore's talk on his days as a programmer and operator of the Whirlwind is covered in this issue of the Report.

June 23. Gwen Bell outlined the museum's taxonomy for classifying calculating devices and computers.

June 30. Alan Kotok, one of the author's of Space War on the PDP-1 at MIT, demonstrated the program, and described the original environment of the machine.

July 7. Maurice Wilkes walked along the Pioneer Computer Timeline reminiscing about the people and events portrayed on it.

July 14. Paul Ceruzzi, one of the first Charles Babbage Institute fellows and professor of Computing History at Clemson University, spoke on the evolution of the "computer age".

July 21. TX-0's only technician, John McKenzie, pointed out the features of the machine and noted highlights from its era at MIT.

July 28. Bob Glorioso spoke about his experiences with vacuum tubes, transistors, and integrated circuits, many of which he collected and has donated to the museum.

August 4. "The Thinking Machine" a 1960 television special featuring early work at MIT in Artificial Intelligence and the TX-0 was shown.

August 11. As part of the development of the exhibit of the sieve machines built by Derek Lehmer, Dick Rubinstein spoke about their principles and evolution.

August 18. The early development of integrated circuits at Texas Instruments was described by Jeff Kalb.

August 25. "Atavistic Beginnings of Personal Computers" was the final session given by Geoff Feldman and Rick Jevon, who worked at The Computer Store, the first retail outlet for personal computers.

FOUNDERS

Until June 1984, the opportunity exists for corporations and individuals to become Founders of the Museum. This provides a unique, opportunity to initialize a new major institution. The original set of 11 Corporate Founders and 51 Individual Founders were listed in the first Report.

New Corporate Founders:

Benton and Bowles
Intel Corporation
Richard Reno

New Individual Founders:

Charles W. Adams
Michael and Merry Andelman
Isaac O. Auerbach
Leo L. Beranek
Eric Bloch
George A. Chamberlain III
Harvey Cragon
Edson de Castro
Harvey and Barbara Deitel
Georgedna Doriot
Jay W. Forrester
Alan Frisbie
Samuel H. Fuller
Margaret A. Herrick
Peter S. Hirshberg
L. R. Jasper
R. L. Lane
Harold W. Lawson, Jr.
John V. Levy
Julius L. Marcus
Thomas and Elizabeth McWilliams
Richard G. Mills
Martin O'Donnell
J. Porter
Brian Randell
Ronald G. Smart
John Stark
Max J. Steinmann
Robert E. and Diane M. Stewart
Norman H. and Robert W. Taylor
William R. Thompson
Fritz and Nomi Trapnell
An Wang
Thomas E. Welmers
William Wolfson

The Computer Historian's Bookshelf

The Museum's bibliophiles have agreed on a list of books that they would have in their own libraries. To make it easy for you to have this collection, all the books have been stocked in the Museum store and can be ordered using the form at the back of this *Report*.

We began by considering all the books in Bill Aspray's and Brian Randell's bibliographies and ordered the ones in print. Then, we started our own review process, both adding and eliminating books. After reading several reviews and the books, we agreed on a short extract to use in characterizing the book.

The final step was to classify the books. Four categories resulted: History; Pre-history; Recreational Reading; and Reference.

We'll keep track of the "best sellers" and incorporate your recommendations and evaluations into future book lists.

Gwen Bell
Ben Goldberg
Beth Parkhurst
Dick Rubinstein
Allison Stelling

HISTORY

Annals of the History of Computing, Vol. 3, No. 4, October 1981, illustrations and diagrams.
Order: ANN81 $8.00

This classic issue of the Annals is devoted to an insider's view of the first general-purpose electronic computer. The ENIAC monograph by Arthur W. Burks and Alice R. Burks presents a well-reasoned view of ENIAC's place among computer developments of the day, and gives a long-needed description of the machine's design logic, circuitry, and problem set-up. Comments by J. G. Brainerd, J. P. Eckert, K. R. Mauchly, B. Randell, and K. Zuse follow.
Beth Parkhurst

A History of Manchester Computers, by Simon Lavington, 1975, National Computing Centre, Manchester, England, fully illustrated, 44 pages.
Order: LAV75 $6.50

"This very useful booklet summarizes the history of five successive computer projects at Manchester University, during the period 1946-1975. The early pages give information, from primary sources, on the development of the first computer at Manchester, and on the roles of F. C. Williams, T. Kilburn, M. H. A. Newman, A. Turing, and others. Profusely illustrated." Brian Randell

An Age of Innovation: The World of Electronics, 1930-2000, by the editors of Electronics, 1981, McGraw-Hill, New York, fully illustrated.
Order: ELE81 $18.50

"A coffee-table book for everyone interested in electronics . . . the history is accurate and interesting, perhaps more interesting for the nostalgia it stimulates. . . . Much less satisfactory are the last sections, which attempt a view of the future of electronics." Eric A. Weiss in the *Annals of the History of Computing*

History of Binary Numbers and Other Non-Decimal Numeration, by Anton Glaser, 1981, Tomash Publishers, 218 pages.
Order: GLA81 $28.00

". . . a carefully revised version of the author's Ph.D. thesis. . . . The coverage is extensive and very well written . . . makes a significant contribution to our understanding of the complex world in which we live." *Annals of the History of Computing*

25 anniversary issue, IBM Journal of Research and Development, Vol. 25, No. 5, September 1981, 846 pages.
Order: IBM81 $6.00

A very rich volume chronicling the technical achievements of IBM in six areas: System Architecture and Development; Software Technology; Component Development and Manufacturing Technology; Magnetic Recording Technology; Printing Technology; and IBM Scientific Contributions.

Computers: From Pascal to Von Neumann, by Herman H. Goldstine, 1972, Princeton University Press, Princeton, New Jersey, 378 pages with 14 illustrations, paperback.
Order: GOL72 $6.95

"An interesting work dealing briefly with the development of the computer from the 17th Century to the 1930's, and extensively with the work of the author, John von Neumann and others. . . . Their creation of the first electronic digital computer, ENIAC, during World War II, and postwar developments at the Institute as part of the burgeoning world-wide 'computer revolution' make up the major portion of this fascinating view of the computer world." C. R. LeSueur, *Library Journal*

Antique Scientific Instruments, by Gerard L'E Turner, 1980, Blanford Press Ltd., Poole, Dorset, 69 color plates, 168 pages.
Order: TUR80 $20.00

The author, Senior Assistant Curator of the Museum of the History of Science, Oxford University, has collected his illustrations and materials from a variety of European museums and collections. The first four chapters on astronomy and time-telling, navigational instruments, surveying instruments, and drawing and calculating instruments are particularly relevant to the pre-history of computers. The last chapter, "Practical Advice on Collecting," will be especially useful to collectors. Gwen Bell

Computer Engineering, A DEC View of Hardware Systems Design, by C. Gordon Bell, J. Craig Mudge, and John E. McNamara, 1978, Digital Press, 561 pages.
Order: BEL78 $28.00

"This book attempts to cover the entire Digital Equipment Corporation product line starting with the early module series and the PDP-1, including such popular computers as the PDP-8, PDP-10, and PDP-11. . . . For everyone interested in how and why computers and digital systems are designed and implemented, whether student or experienced practitioner, this book is a must." L. A. Hollaar, *ACM Computing Reviews*

A History of Computing in the Twentieth Century, edited by N. Metropolis, J. Howlett and Gian-Carlo Rota, 1976, Academic Press, Inc., New York, 659 pages with 121 illustrations and photos and 4 tables.
Order: MET76 $29.50

"If you've been thinking that some day you should read something on computer history, buy this book! It consists of edited versions of papers presented in 1976 at an invitational conference supported by the Los Alamos Scientific Laboratory (and held there) and by the National Science Foundation. The authors of the 37 papers include a high percentage of the people who personally did the pioneering work in computing or were firsthand witnesses to it." D. D. McCracken, *Computing Reviews*

The Origins of Digital Computers: Selected Papers, edited by Brian Randell, 1975, Berlin, Springer, bibliography.
Order: RAN75 $35.00

"An outstanding collection of excerpts from important nineteeth and twentieth century computer developments, together with background and commentary on each excerpt." William Aspray

Project Whirlwind: The History of a Pioneer Computer, by Kent C. Redmond and Thomas M. Smith, 1980, Digital Press, Bedford, Massachusetts, 67 illustrations and diagrams, 280 pages.
Order: RED80 $25.00

"This book is not a technical engineering account. Instead, it is an attempt to reconstruct the complexity of technical, financial, and administrative problems and the eventual compromises and solutions to these problems." Henry S. Tropp in the *Annals of the History of Computing*

From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers, by Nancy Stern, 1981, Digital Press, Bedford, Massachusetts, 38 illustrations and diagrams, appendix, 286 pages.
Order: STE81 $25.00

"This volume is derived from Nancy Stern's Ph.D. thesis. . . . The emphasis is on people and environment. . . . The volume is handsome and is enhanced by a large number of illustrations and diagrams." Henry S. Tropp in the *Annals of the History of Computing*

Early British Computers: The Story of Vintage Computers and the People Who Built Them, by Simon Lavington, 1980, Digital Press, Bedford, Massachusetts, fully illustrated, appendix, 139 pages.
Order: LAV80 $9.00

"This volume, sprinkled with more than 60 photographs, discusses wartime work on Colossus, EDSAC, Pilot ACE, the Manchester Mark I, LEO, and other early British computers." Henry S. Tropp in the *Annals of the History of Computing*

The Computer and the Brain, by John Von Neumann, 1958, Yale University Press, New Haven, 82 pp.
Order: VON58 $3.45

"This book, composed of material prepared for the Silliman Lectures by John Von Neumann before his death, represents the views of one of the greatest mathematicians of the twentieth century on the analogies between computing machines and the living human brain." *Library Journal*

History of Programming Languages, by Richard L. Wexelblat, ed., 1981, Academic Press, New York, 748 pp.
Order: WEX81 $45.00

". . . a very valuable and readable source of historical information on the development of the most important and influential programming languages . . . this is a book that should appeal not just to people with a serious interest in the history of computing but to anybody who has experienced the delights and frustrations of computer programming. . . ." Brian Randell in *Science Magazine*

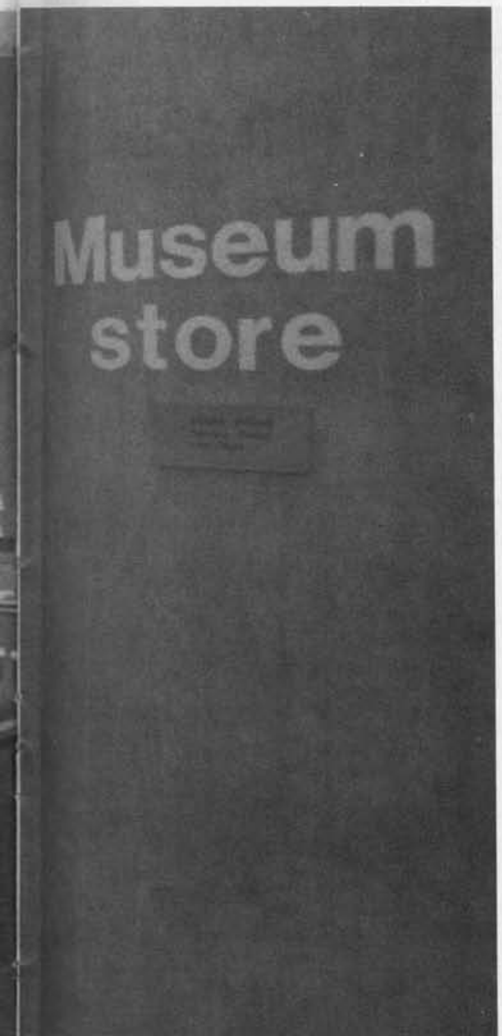
PRE-HISTORY

Origins of Modern Calculating Machines, by J. A. V. Turck, 1972, Arno Press Inc., New York, 196 pages with 38 illustrations.
Order: TUR72 $17.00

"This book is a chronicle of the evolution of mechanical calculating and recording machines including machines such as Pascal's machine, the Comptometer, the Burrough's machine and the Billing's machine. Written in 1921, the book is of historical interest for its unique perspective, its extreme detail and excellent illustrations." Allison Stelling

Collecting Mechanical Antiques, by Ronald Pearsall, Arco Publishing Company Inc., New York 1973, 92 illustrations, 197 pages.
Order: PEA73 $7.95

This book provides an illustrated history of the sewing machine, typewriter, telegraph, telephone, camera, cinematograph, automata and mechanical toys, mechanical music, domestic appliances and gadgets. Gwen Bell



Museum store in action

The Clockwork Universe, edited by Klaus Maurice and Otto Mayr, Smithsonian Institution, Washington, D.C., Meale Watson Academic Publications, New York, 1980, 200 illustrations and technical drawings, 322 pages.
Order: MAU80 $35.00

The book is the catalog of the exhibition The Clockwork Universe produced jointly by the National Museum of History and Technology, Smithsonian Institution and the Bayerisches Nationalmuseum, Munich. In fourteen contributions from European and American scholars, the book depicts the golden age of German clockmaking, 1550–1650 with detailed physical descriptions of the finest clocks, automata and mechanical celestial globes surviving from the time. Gwen Bell

A History of the Machine, by Sigvard Strandh, 1979, A&W Publishers, Inc., New York, fully illustrated with diagrams, 234 pages.
Order: STR79 $35.00

The author, Director of the National Museum of Science and Technology in Stockholm, has put together an explanatory illustrated text that is second best to going to a good science museum. Chapter 8, Computers, has excellent diagrams ranging from the workings of the Jacquard loom to the inside of the HP-35. Other chapters cover early machines, tools and robots, windmills, engines, electricity, control systems, and household tools. Gwen Bell

Early Scientific Instruments, by Nigel Hawkes, 1981, Abbeville Press, Inc., New York, 73 full page color illustrations, 164 pages.
Order: HAW81 $30.00

"In this book are illustrated important examples from the diverse range of artifacts with which man has tried to discover and explain the complexities of the physical world, and, through this comprehension, use nature for his own ends. These early instruments, in addition to providing a tangible record of the development of scientific knowledge, vividly demonstrate the technical ingenuity of former times."
D. J. Bryden in the Introduction

RECREATIONAL READING

Micromillenium, by Christopher Evans, 1979, The Viking Press, New York, 255 pages.
Order: EVA79 $10.95

"[This is an] enthusiastic and optimistic review of the past, present, and, especially, future [of computers]. . . . Informative, fast-paced, and well-organized, the book is eminently readable. . . ." B. C. Hackler, *Library Journal*

The Computer Establishment, by Katharine Davis Fishman, 1981, Harper and Row, New York, 468 pages.
Order: FIS81 $20.95

"Mrs. Fishman has written a splendid study of the computer revolution. This is not the book from which to learn the details of computer technology (although such technical material as it contains is presented with great economy and clarity), but it is definitely a book from which to learn about the computer industry."
The New Yorker

Discovering Computers, by Mark Frank, 1981, Stonehenge Press Inc., London, 96 pages with 104 illustrations and photographs.
Order: FRA81 $9.95

This book from an excellent series for young people does justice as a child's introduction to computers. Appropriate for junior high level, Frank's book was written expressly for readers with no previous knowledge about computers, math, or science. It describes how computers function and what computers can and cannot do. Chris Rudomin

The Enigma War, by Jozef Garlinski, 1980, Scribner, New York, 211 pp.
Order: GAR80 $14.95

"Historians of WW II and specialists in intelligence cryptanalysis will find Garlinski's study indispensible; it is the most detailed, corroborated account of the development and perfection of the "Enigma" machine by which the Allies were able to decipher a great portion of the strategically important Nazi and Japanese radio messages from 1940 onward." *Choice Magazine*

The Soul of a New Machine, by Tracy Kidder, 1981, Little, Brown and Company, Boston, 293 pages.
Order: KID81 $13.95

"Kidder . . . provides a feeling for what this new and ever-changing technology is all about. He tells a human story of enormous effort; yet, eerily, it is the Eagle itself that emerges as the book's hero."
Saturday Review

Microelectronics Revolution, by Tom Forester (ed.), 1980, M.I.T. Press, Cambridge, Massachusetts, 589 pages with 104 photographs and illustrations, paperback.
Order: FOR80 $12.50

"Editor Forester, a journalist, presents 41 pieces written from the mid- to the late-1970's on a technology that could revolutionize our lifestyles and work habits while displacing major segments of the labor force in a sort of second Industrial Revolution. Several chapters outline the technical side of microelectronics, but all are within the layperson's grasp, and the book concentrates on the social implications of the technology. . . . This is one of the more thorough treatments available on the subject." Barbara Gaye, *Library Journal*

Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence, by Pamela McCorduck, 1979, W. H. Freeman and Company, San Francisco, 364 pp.
Order: MCC79 $8.95

"In this delicious book—witty, informed, open, rich in direct and candid testimony—a novelist reports her visits among the ambitious projectors and her estimates of what they do, say, and plan. She offers a good deal of wise reflection but never one flowchart or formula." P. Morrison, *Computing Reviews*

Hut Six, by Gordon Welchman, McGraw-Hill Book Company, New York, 1982, 326 pages.
Order: WEL82 $12.95

"A fascinating account of the breaking of the German 'Enigma' code which took place at Bletchley Park in England. The author was deeply involved in the cryptanalysis project, and thus presents a very personal history of the events leading up to the codebreaking. The book offers an excellent insight into the personalities involved in the project. The last section of the book is devoted to an analysis of the current state of the communications systems in the U.S. defense program, a scathing critique." Ben Goldberg

REFERENCE

Electronic Inventions and Discoveries, by G. W. A. Dummer, Pergamon Press, Oxford, 2nd edition, 1978, 204 pages.
Order: DUM78 $20.00

The meat of the book is a brief description of each electronic invention in date order. The work is fully indexed by subject, invention, and inventor. Interesting descriptions and illustrations make the book fun for browsing as well as useful for reference. Gwen Bell

Data Processing Technology and Economics, by Montgomery Phister, Jr., 1979, Digital Press, Bedford, Massachusetts, 717 pages with 535 illustrations and 261 tables, paperback.
Order: PHI79 $33.00

"An updated version of this original marvelous tome of copious data-processing-related facts and figures. This would represent the data-processing equivalent of the annual information almanacs—if it were made current more frequently. Unqualifiedly superb as a reference work, it also makes for fascinating browsing." *Choice*

Computer Dictionary, by Charles J. Sippl and Roger J. Sippl, 1982, Howard W. Sams & Co., Inc., Indianapolis, 624 pages with 55 photos and illustrations, paperback.
Order: SIP82 $15.95

"This is a 'browsing' dictionary. . . . Many definitions and explanations are long and are designed to be so. Users of this book can easily and leisurely browse through the main and supplemental 'areas,' such as 'data base,' to learn significant details about the products, procedures, problems and proliferating applications." *Preface, Computer Dictionary*

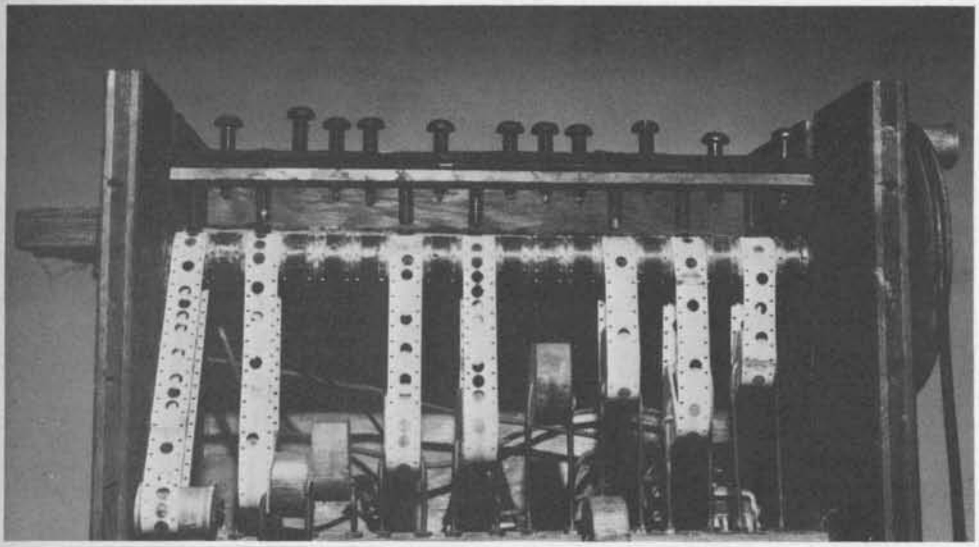
The Opening Poster
Order: 61082 $4.00

Full color, 20 × 30 inch poster commemorating the opening of the Museum. The photograph shows the vacuum-tube power driver of the first core memory bank for Whirlwind, 1953, and a prototype integrated circuit for the Apollo Guidance Computer, 1965.

1983 Calendar: The Computer Era, 9 × 12 folded, spiral bound, heavy coated paper.
Order: YEA83 $7.95

This calendar is illustrated with photos of contemporary computing systems or components from major manufacturers along with equivalents from the early age of computing. The major historic events that can be pinned down to an exact day, such as Babbage's birthday, the announcement of the IBM 360, or Stibitz's 1940 demonstration of calculating via teletype from Dartmouth to New York are recorded. The calendar is beautiful, informative and fun. Gwen Bell

Future Museum Lectures
Thursday Afternoons at 5PM



October 7 **D.H. LEHMER**

HISTORY OF THE SIEVE MACHINES

The 1936 electro-mechanical sieve shown at left is one of Derek Lehmer's sieve process machines, devices which aided in solving certain equations using principles of number theory. He has donated three complete sieves and plans for his 1926 bicycle-chain machine to the Museum. His lecture will describe the evolution of these machines from 1926 to the mid fifties, and commemorate the opening of their exhibition at the Museum.

October 21 **HERBERT J. GROSCH**

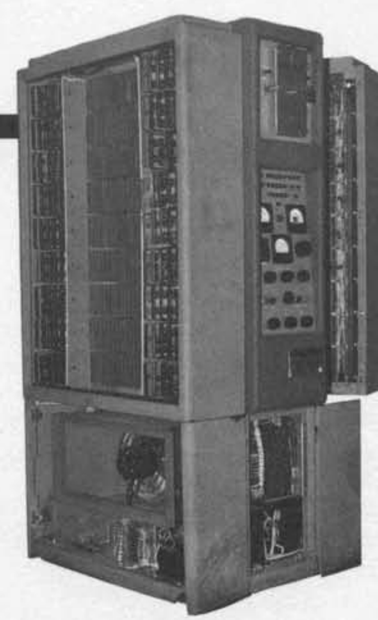
THE WATSON SCIENTIFIC LABORATORY 1945–50

As the first assistant to Wallace Eckert and director of the computing program, Herbert Grosch will provide a narrative of the development of the Columbia Laboratories up to the time of NORC.

November 18 **HARRY HUSKEY**

FROM PILOT ACE TO G-15

As a Fulbright scholar, Harry Huskey spurred the building of the Pilot ACE at Britain's National Physical Laboratory. Returning to the USA, he was the chief designer of the SWAC and the Bendix G-15. His lecture will provide a chronicle of the evolution from single laboratory to commercial computers.



The Bendix G-15

THE END BIT 0000000000000001

A newsbrief of the collection

One of the first NOVA central processing units, a recent gift from Data General, is currently exhibited with its original advertising photographs and engineering drawings at the Museum. Introduced in 1968, the NOVA was priced at $8,000 with mixed and matched RAM and ROM to 32,000 words.

The CPU, located by Kris Eberlin of Data General, is the 203rd unit manufactured by the company. The NOVA can be seen in the Four Computer Generations gallery. The Museum's newest exhibition, the gallery highlights major technological inventions, significant hardware and software, and computer applications.

The
Computer
Museum

One Iron Way
Marlboro
Massachusetts
01752