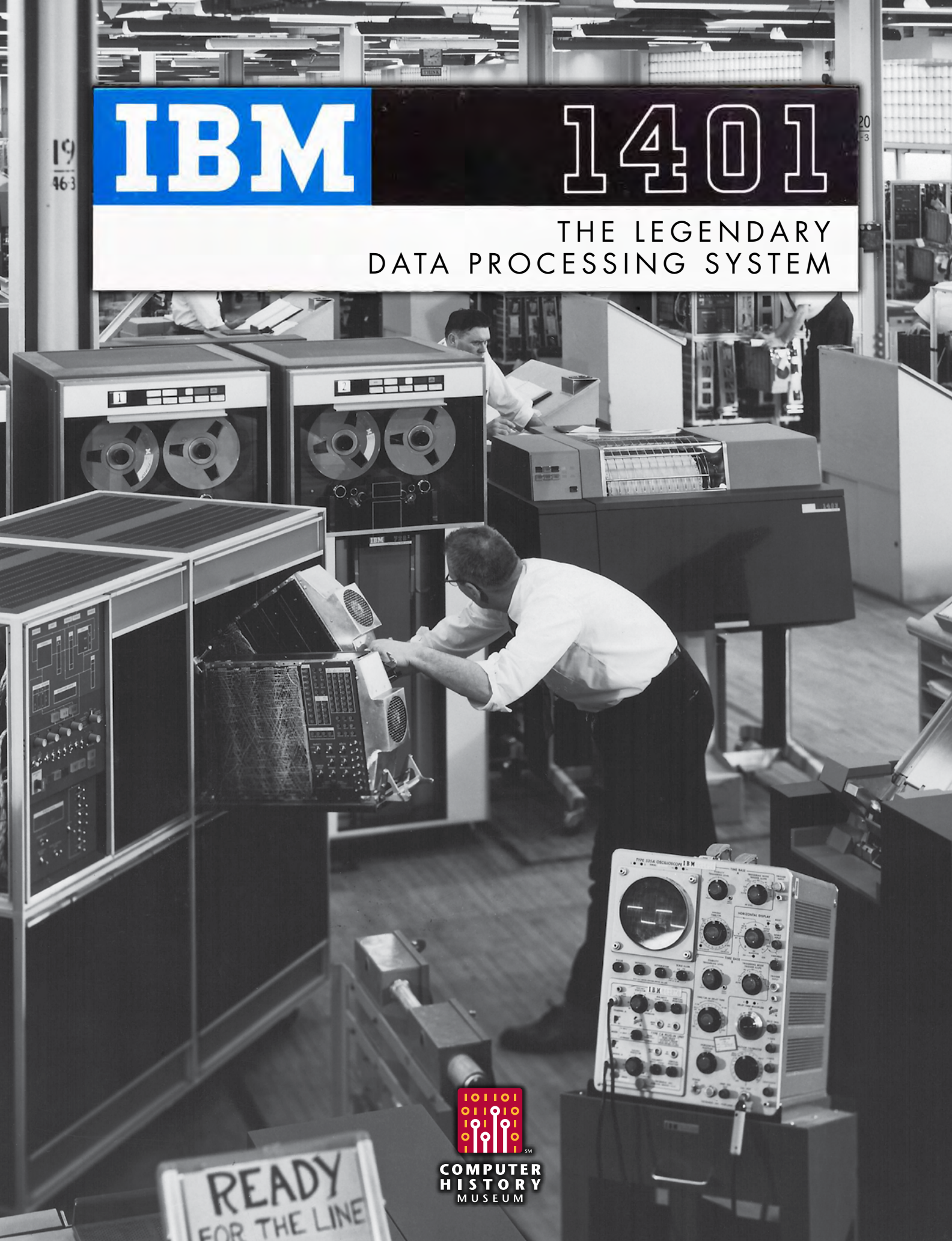

IBM
1401
THE LEGENDARY
DATA PROCESSING SYSTEM
READY
FOR THE LINE
COMPUTER
HISTORY
MUSEUM

2 FOREWORD DAG SPICER

Image courtesy of IBM Archives

This commemorative booklet has been prepared to acquaint you with a computer in the Museum's collection that has had dramatic social, technical and economic consequences and which has been brought back to life by Museum volunteers. This mass-produced computer, the IBM *1401* Data Processing System (1959), reflected a need by industry and government to process rapidly growing amounts of information quickly. In responding to this need, the *1401* system itself shaped the solutions people used across a broad range of problems.

For many customers, this was the first computer they had used. New procedures had to be simple, while still respecting existing punched card methods, and allow for an optional transition from punched card procedures to tape and disk-based methods. The *1401* did this with optional tape and disk attachments that allowed customers to begin moving away from the storerooms (sometimes warehouses) of punched cards they had accumulated onto more compact formats. A single reel of magnetic tape could store the equivalent of tens of thousands of punched cards while disks allowed in-line data processing and the rapid random access of data that punched card and tape systems lacked.

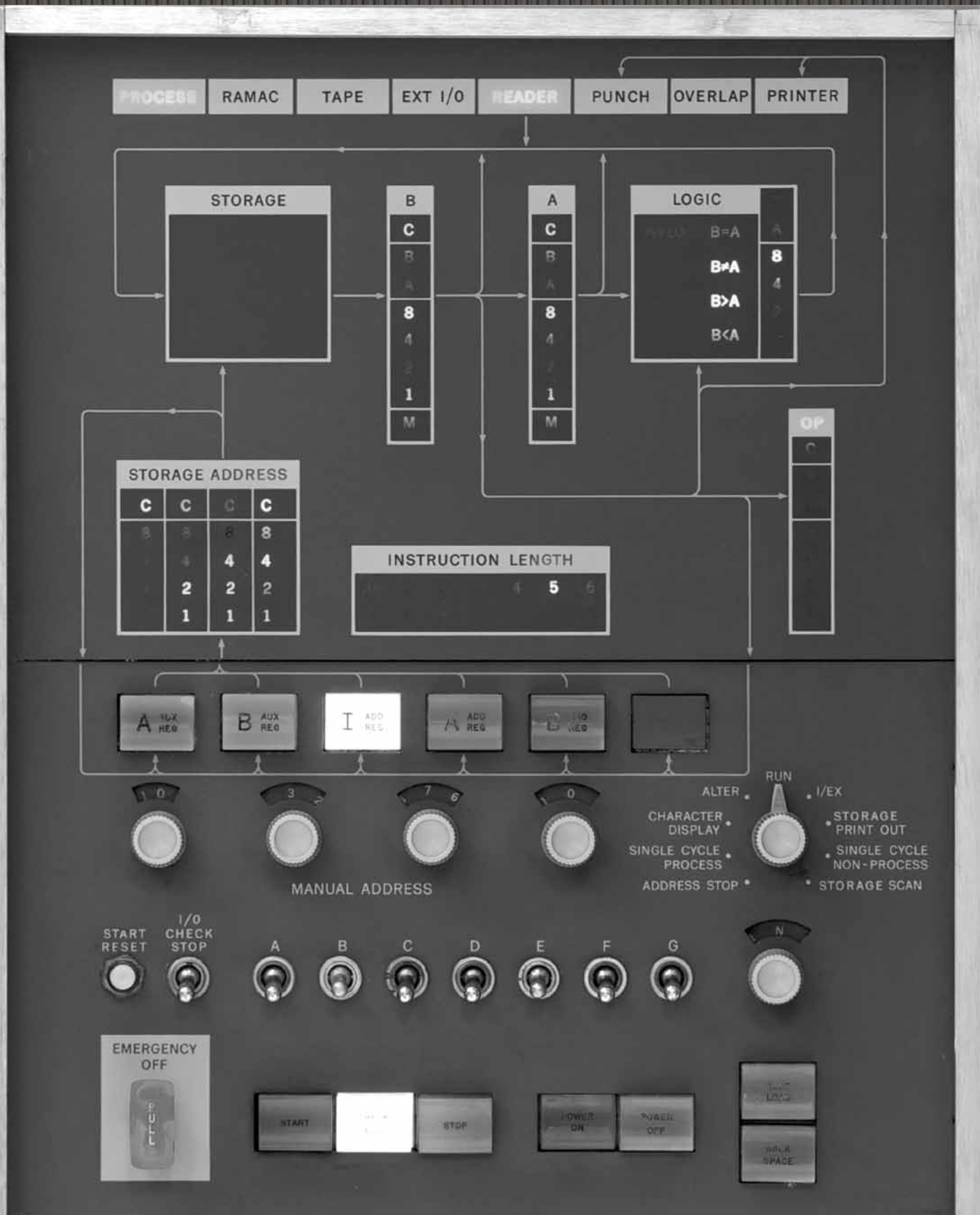
The *1401* was installed by the thousands over its lifetime, reshaping the way the world handled information by providing an inexpensive, reliable system incorporating straightforward procedures and tools covered a wide variety of tasks. There were other systems, of course, but the IBM machine (and its follow-on family members) was the Chevrolet of the computer world for much of the 1960s.

At the Computer History Museum, we have been most fortunate in being host to a team of volunteers for whom the *1401* played a significant personal role in their lives. This group has brought their energy to bear on bringing a *1401* system (actually, two) back to life. As you will see later in this booklet, the team faced serious obstacles at times but persistence and talent carried them through.

It is a delight to reflect upon the social and technical changes that the *1401* system had in its quiet way. Nearly invisible to history now, it was a stage upon which played out the delicate choreography between machine and user that is typical of all tools but which had new variations based on the computer's unique qualities as well. I hope you will enjoy this booklet, invite you to enjoy the celebration of this remarkable computer system, and, above all, encourage you to see it in operation here at the Museum. ◻

Generous financial support for The 50th Anniversary of the Legendary IBM *1401* event, as well as publication of this commemorative booklet, is made possible by IBM Corporation.

Special thanks to Computer History Museum volunteer Robert Garner and the CHM *1401* Restoration Team for their enthusiastic efforts and talent in planning and executing this anniversary celebration.



Photograph by Marcin Wichary

THE IBM *1401* WAS THE WORLD'S MOST POPULAR COMPUTER during much of the 1960s. By mid decade, half of all computers in the world were *1401*s or related members of the *1401* family.

The *1401* introduced thousands of businesses and institutions to stored-program computing while its tape and disk systems freed them from the decades-long practice of storing data on punched cards. Additionally, the *1401* was one of IBM's earliest transistorized computers.

BACKGROUND

For the first six decades of the 20th century, business data processing—inventory, billing, receivables, payroll—was accomplished by repetitiously passing decks of punched cards through various electro-mechanical accounting machines to sort, calculate, collate, print and punch. Each machine was controlled by a hand-wired plugboard tailored for a particular job.

In contrast, stored-program computers, considerably more flexible and adaptable, were nevertheless too expensive for all but the largest corporations, renting for around $30,000 per month ($200,000 per month in today's currency) versus around $2,500 per month for several accounting machines.

ORIGINS

In 1957, in Endicott, New York, IBM systems architect Francis Underwood bucked conventional wisdom that stored-program computing was too expensive for the mass market. His low-cost stored-program computer was designed to satisfy the needs of accounting machine users while being easy to program.

Underwood named his processor design SPACE, for Stored-Program Accounting and Calculating Equipment—striking a responsive chord as Sputnik had just launched in October. He also discerningly leveraged the data path design from a transistorized accounting machine project (known as the World-Wide Accounting Machine, WWAM) overseen by IBM World Trade beginning in 1955 in France, where a competitor had been outselling IBM accounting machines and calculators.

With an ambitious entry-system rental target of only $2,500 per month ($20,000 in today's currency), the engineering program manager, Charles Branscomb, tenaciously worked with IBM's computer technology groups on standardized modular circuits, packaging and memory to meet the *1401*'s requirements for low cost and high reliability. He also adopted a high-speed printer *(1403)* already under development and later incorporated a magnetic tape drive controller, enabling card-to-tape and tape-to-print transfers to large-scale mainframes.

By mid-1959, with a 40-person engineering team working night and day, trial educational classes underway within IBM, and a running prototype that achieved the entry-level cost target, the *1401* was poised to transform the business world with its low price, outstanding print

Image courtesy of IBM Archives

Image courtesy of IBM Archives

TOP A typical card accounting machine "unit-record" shop (1950s) MIDDLE Clockwise from upper left: Branscomb, Underwood, Jacobs, Ingram Jr BOTTOM French, German and U.S. task force formulating the WWAM (1955) OPPOSITE Console indicators and switches

Image courtesy of IBM Archives

Image courtesy of IBM Archives

Image courtesy of IBM Archives

TOP The *1401* Datamobile, on tour throughout Europe, at the foot of the recently built Atomium in Brussels (1960) MIDDLE *1401* processor main frame manufacturing, Endicott (1960) BOTTOM Graduating class of IBM customer engineers, Rochester, MI (1961)

quality, powerful magnetic tapes, and the promise of a mass-market stored-program computer.

"DAWN OF A NEW AGE"

On October 5, 1959, the *1401* was announced via closed-circuit TV to 50,000 participants in 102 cities. In September the following year, the first *1401* was shipped to Time-Life in Chicago and by year end 100 systems had been delivered.

INSTALLED BASE

The *1401* was very successful. By 1965, worldwide installations peaked at 9,300 systems while *1400* family machines—models *1410, 1440, 1460, 7010*—comprised half of all computers. The total number of *1400* family computers peaked in 1967 at about 15,000 systems.

IBM *1401* reliability was renowned and many systems operated around the clock. IBM had a large organization of Customer Engineers (CEs) that worked closely with users to maintain their systems.

SYSTEM SCALE & COST

Known as a small-scale computer, a full *1401* system comprised about 500,000 components, weighed four tons and consumed 13,000 watts!

Most *1401s* were leased. Rental for an entry level system was $2,500 per month, comparable to the three accounting machines and calculator they were to replace. A typical *1401* system rented for $6,500 per month or cost $500,000 to purchase outright ($45,000 and $3.4 million in today's currency), about one-sixth the cost of a large-scale mainframe.

PROCESSOR ARCHITECTURE

The *1401* was a character-serial decimal arithmetic computer. A single character or digit was stored per memory position and numbers or strings of numbers or characters could be arbitrarily long (up to the size of memory).

Memory ranged in capacity from 1,400 to 16,000 positions, each position holding eight bits: 6-bit character or digit, an end-of-field "word mark" bit, and an odd parity or "check" bit.

The *1401* processor clock frequency was 87 kilohertz, for an 11.5 microsecond cycle time. Transferring a character every processor cycle, this rate was well-balanced to the *1401* mechanical peripheral data rates. Fifty processor cycles were needed to add 20-digit numbers, about a million times slower than a modern personal computer adding 64-bit numbers!

TECHNOLOGY

The *1401* processor contained about 2,300 Standard Modular System (SMS) printed circuit cards, each about 2.6" wide by 4.5" long. Thick gold

contacts helped to insure system reliability. By 1958, IBM had built a fully automated in-house SMS assembly and test line.

The SMS Cube system could package up to 144 cards per chassis gate, which swung outward 90° for card access. Reliable pin-to-pin wire-wrap technology was used for interconnects.

The *1401* used discrete germanium alloy-junction transistors and point-contact diodes. By 1958, IBM had designed and built an entirely automated alloy-junction transistor production line, which was then transferred to Texas Instruments a year later.

Core memory was a three-dimensional stack of meshes of tiny magnetic donuts threaded with fine wires. By 1956, IBM had a fully automatic in-house core manufacturing facility. The memory was priced at 60 cents per bit, or $24 per byte in today's dollars—300 million times more expensive than today's DRAM.

SOFTWARE

IBM offered Autocoder and SPS (Symbolic Programming System) assemblers for machine-level programming, FORTRAN, COBOL, and Report Program Generator (RPG) compilers, and sort and I/O utilities. IBM did not have an operating system for the *1401* (but did for the *1410*).

COMPETITION & SUCCESSION

In late 1963, Honeywell challenged IBM's market dominance by announcing the faster and more capable H200, along with "Liberator" software that ran *1401* programs unmodified.

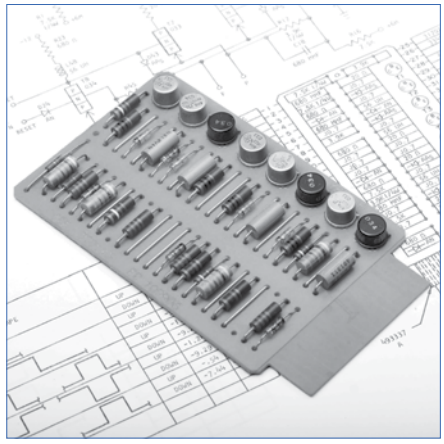
In 1961, IBM began planning for the unification of its various incompatible computer lines. Announced April 1964, the System/360 consolidated software, peripherals and support into one family. One key technology was a flexible "control store," which enabled the low-end System/360 Model 30 to be used as a *1401* replacement, thereby holding the fort against the Honeywell H200.

Although the development of *1400*s wound down after the announcement, this computer family outnumbered *360*s as late as 1967.

LONGEVITY

The *1401* was offered by IBM until 1971. No-one can say for sure when the last *1401* was shut down, but at least one machine was used to operate a small personal business as late as 1995, and today *1401* PC-based simulators are available.

The *1401* resurfaced in popular culture in 2001 when a young Icelandic composer, Jóhann Jóhannsson, scored the symphonic composition *IBM 1401: A user's manual*. Jóhannsson was inspired by a tape recording of *1401* "radio music"—sounds induced into a nearly AM radio via execution of particular *1401* code sequences—made by his father at its 1972 decommissioning ceremony. This original symphonic composition may be the only human-composed music written for and dedicated to a computer. ◻



Photograph by Marcin Wichary

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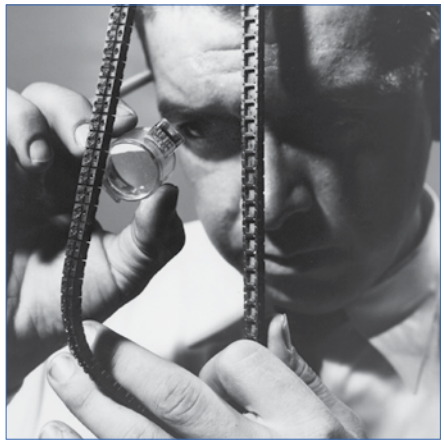


Image courtesy of IBM Archives

TOP Example Standard Module System (SMS) circuit card used by the *1401* processor MIDDLE Internal structure of a germanium alloy-junction *n-p-n* transistor used in the *1401* BOTTOM The *1403* print chain removed from its housing

1401 SYSTEM & PERIPHERALS

729

Various models of the magnetic-tape vacuum-column drive, developed for the 7000-series mainframes, were able to transfer data at 15,000 to 62,500 characters per second, access tape records at 75 or 112.5 inches per second, and rewind a 2400-foot, 13-million character tape in under a minute. One magnetic tape could hold up to 50,000 punched cards' worth of data.

1407

The Console Inquiry Station used an IBM Selectric typewriter to print messages for the operator. It also included a duplicate set of front panel switches and indicator lights.

1403

The printer's high speed and **ENDURING PRINT QUALITY** made it an industry workhorse. It could print 132 columns at 600 lines per minute and its hydraulic carriage could quickly skip over blank lines at 33 inches per second. Multiple hammers fired together when the proper characters on a horizontally rotating chain were in position, slamming the paper, inked ribbon and chain character slug together. The *1403* could support multiple character sets via different chains.

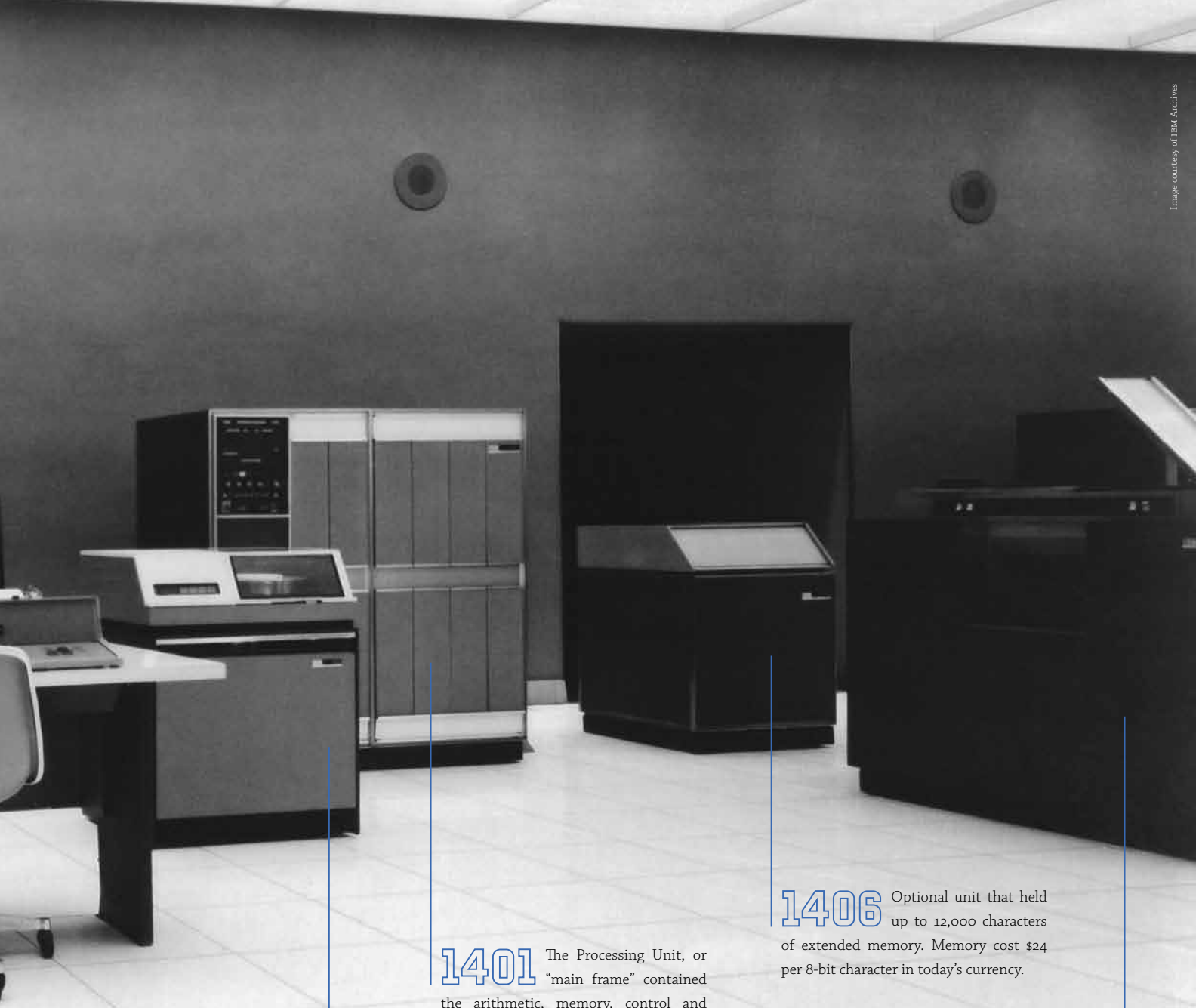


Image courtesy of IBM Archives

1311 The first storage design with removable disk packs. Designed at IBM's new R&D lab in San Jose, each pack held two million characters and contained six 14-inch-diameter disks in a four-inch stack, weighing ten pounds. The disks rotated at 1,500 rpm.

1401 The Processing Unit, or "main frame" contained the arithmetic, memory, control and peripheral interfaces. It operated on character strings and performed arithmetic serially, one character or decimal digit per cycle. Numbers and strings could be arbitrarily long. With a cycle time of 11.5 microseconds—87,000 cycles per second—it was well-balanced with the speed of its mechanical peripherals.

1406 Optional unit that held up to 12,000 characters of extended memory. Memory cost $24 per 8-bit character in today's currency.

1402 The card read-punch unit provided for simultaneous punched-card input and output. It could read 800 cards per minute or punch 250 cards during the same time. Cards could be directed to one of five hopers and its "file feed" input station could hold up to 3,000 cards.

Photograph by Marcin Wichary

Two complete *1401* systems, today 45 and 48 years old, were brought back to life by a team of about 20 volunteers, including retired IBM engineers that had supported *1401*s at customer sites, in manufacturing, and in design. Considering that each system contains approximately half a million discrete components, the successful restoration highlights the strength of the *1401*'s design and outstanding reliability of its mechanical and stolid-state components.

THE GERMAN 1401

The first restoration story begins in the fall of 2003, when a *1401* system was spotted on a German auction website. After expiring without a bid, its owner, Arnold Schweinberg, indicated his willingness to offer it to the Computer History Museum. But how was the CHM going to restore a 40-year-old computer with several hundred thousand mechanical and electrical components in unknown condition and unused for nearly 30 years? Having recently joined IBM and knowing nothing about that company's early computers, but also having a positive feeling for the educational value of a restored "compusaur," I decided what better way to learn firsthand IBM history than to lead the 1401 restoration project.

Luckily, an IBM colleague in Mainz was able to inspect Arnold's *1401* and found it to be in reasonable condition, notwithstanding corrosion in its *1402* punched card unit. Arnold had employed the *1401* for his small service business for five years, taking it over from an insurance company that had operated it 24/7 for eight years. Following the establishment of a CHM acquisition fund from several donors, IBM European Logistics handled the crating and transportation from Hamm, Germany to Mountain View, California, with IBM Almaden Research covering the costs.

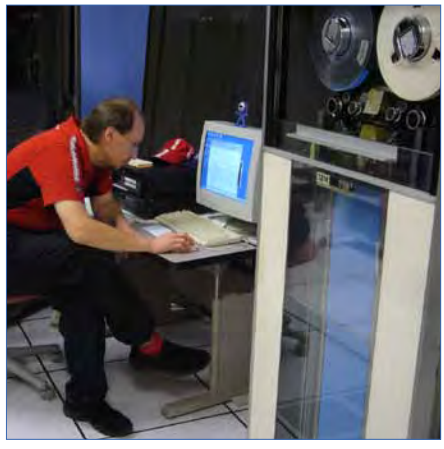
Before arriving in March 2004, I had placed "An IBM *1401* Needs Help" advertisement in the San Jose IBM Retirement Newsletter. Over a dozen retired IBM engineers responded enthusiastically. After several strategy sessions, assessments, recounting of servicing methods, copying of documentation, restoring of internal power supplies on the lab bench, and acquisition of a 60-to-50 Hz power converter, the *1401* was powered up afresh in November 2004.

FIRST LIGHT

The new CHM restoration team established a regular schedule: Wednesdays for the main team, Thursdays for the tape drive team, and the 2nd and 4th Saturdays of the month for everything else. A managed web site was setup to document all the activities.

By the fall of 2004, the *1401* was running simple diagnostic programs—"first light" as it was called—and by May 2008 it was fully operational (with half of its four *729*s tape drives). "Bug shooting" was done by using an oscilloscope, volt-ohm meter and other helpful period tools while pouring over binders of schematics. A custom embedded microprocessor and analog electronics controller was built to emulate

Photograph by Robert Garner



Photograph by Robert Garner

Photograph by Marcin Wichary

TOP Volunteer Bob Erickson shooting a bug in *1406* core memory stack MIDDLE Volunteer Sam Sjogren working on the team's custom-designed *729* tape drive emulator BOTTOM Volunteer Ron Williams mounting magnetic tape on *729* drive OPPOSITE IBM customer engineer tool case

TOP AND OPPOSITE BOTTOM *1401* restoration room: IBM *083* sorter in forefront, German machine front, Connecticut machine rear. Volunteers pictured, left to right: Ron Williams, Don Luke, George Ahearn, Joe Preston, Frank King, Glenn Lea, Bob Erickson BOTTOM Volunteers Ron Williams, Bill Flora, Glenn Lea and Frank King clearing a card jam from the *1402* punch unit OPPOSITE Repair of a broken core memory wire

Photograph by Robert Garner

729 tape drives in order to bring-up the tape interface logic. Out of about 3,000 SMS circuit cards in the system, 130 were found to be defective—not unreasonable after 28 years of storage in an auto garage. Most of the SMS card failures were due to transistors and diodes with ferrous corroded leads, weak or leaky transistors (likely due to in gassing of air), open or shorted or broken diodes, and latches acting like one-shots. In addition to spare cards, "new old stock" transistors were available on the Internet.

Remarkably, no problems were found in the thick cable bundles between system units or in the thousands of inter-card signal wires that are wire-wrapped to backplane pins. The *1403* printer came up quickly and proved to be markedly reliable. Due to moisture-induced corrosion, the *1402* needed card reader and punch unit transplants from another unit in the Museum. The tape drives were retrofitted with new bearings and reformulated magnetic clutches made in a volunteer's machine shop. Software team members "reverse assembled" original *1401* diagnostics and wrote visitor demo software.

THE 1401 FROM CONNECTICUT

The second story begins in the Fall of 2007 with a phone call from the son of a *1401* owner located in Darien, Connecticut. His father, "Buzz" Bellefleur, had operated a small data processing business right from his residence, with the computer located in the basement. He had acquired the four-tape system from an insurance company that had, like the German system, operated it 24/7 for ten years. Since the

German *1401* was regularly yielding defective transistors, I argued to the CHM's Restoration Committee that this second *1401* was necessary for long-term sustainability and continuance. After a reconnaissance trip and fund raising from additional donors, I arranged for a rigging company to extract the system from the home's basement. Also, Buzz had preserved a full set of software distribution tapes, heretofore not known to exist.

With the financial and logistical help of IBM again, the "Connecticut *1401*" arrived in May, 2008. It saw "first light" four months later and was fully operational by September, 2009. Since Buzz had worked on his *1401* as recently as 1995 using air conditioning and a dehumidifier in the basement, only 26 SMS cards were found to be faulty in this system. Perhaps sensing competition, the German *1401* uncannily stabilized the very week its Connecticut sibling arrived.

Photograph by Judith Haemmerle and Ed Thelen

THE ODYSSEY CONTINUES

All told, the *1401* restoration team members have logged over 20,000 hours in 500 work sessions over six years. But more than just work, it's been an odyssey: not knowing what ravage of time will reveal itself next, camaraderie, humor, recounting of past tales, sharing of fun art sculptures, adhering to the the museum's restoration policies, and showing off and demonstrating the systems to visitors and classes.

If you are interested in volunteering or have artifacts or stories to share, please visit the CHM or the *1401* restoration project web site at *www.computerhistory.org/restorations*. ⌑

Photograph by Robert Garner


COMPUTER HISTORY MUSEUM

The Computer History Museum (CHM) is dedicated to the preservation and celebration of the computing revolution and its worldwide impact on the human experience. It is home to the largest international collection of computing artifacts in the world, encompassing computer hardware, software, documentation, ephemera, photographs and moving images.

CHM brings computer history to life through an acclaimed speaker series, dynamic website, onsite tours, as well as physical and online exhibits. We have a wide variety of programs and participation opportunities. Support computer history by becoming involved as a member, attendee, donor, corporate sponsor or volunteer.

CURRENT EXHIBITS IN THE MUSEUM

- **Charles Babbage's Difference Engine №2**
  Designed in the 1840s, the Engine is a stunning display of Victorian mechanics and an arresting spectacle of automatic computing. It consists of 8,000 bronze, cast iron and steel parts, weighs 5 tons, and measures 11 ft. long and 7 ft. high.
- **Visible Storage**
  The Visible Storage gallery features over 600 unique artifacts – from rare slide rules and mechanical calculators to the earliest one-of-kind computers, vintage PCs and exotic supercomputers.
- **Mastering the Game: A History of Computer Chess**
  Our History of Chess exhibit examines computing's five-decade-long quest to build a computer to challenge the best chess players.
- **Innovation in the Valley**
  Learn about the innovators of computing technology in Silicon Valley who have changed our world, including local giants Apple, Cisco, HP, Intel and Sun.
- **Silicon Engine**
  An online and physical exhibit that chronicles important milestones in the evolution of the integrated circuit (IC) and microprocessor. These extraordinary devices power the computing and communications revolution of the information age.
- **Computer History: The First 2,000 Years**
  Our upcoming signature exhibit.

ON THE WEB

- Lecture videos: *youtube.com/computerhistory*
- Volunteer: *computerhistory.org/volunteers*
- Donate: *computerhistory.org/giving*

Photograph by Mark Richards

Photograph by Mark Richards

Photograph by Mark Richards

ABOVE Artifacts from Computer History Museum's Visible Storage OPPOSITE The Museum's building in Mountain View, California

Authors:
Robert Garner
Dag Spicer

Design and photography:
Marcin Wichary

Computer History Museum.
1401 N. Shoreline Blvd.
Mountain View, CA 94043
tel: (650) 810-1010
fax: (650) 810-1055
www.computerhistory.org

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John Shoch
Leonard Shustek
Ronald Williams
Steve Wozniak

Rev. 126. Set in Chaparral and Futura.

RIGHT Long printout on an IBM *1403* FRONT COVER IBM *1401* production line, Endicott, NY, early 1960s PAGES 2–3 IBM tape-oriented *1401* Data Processing System, early 1960s

Image courtesy of IBM Archives