

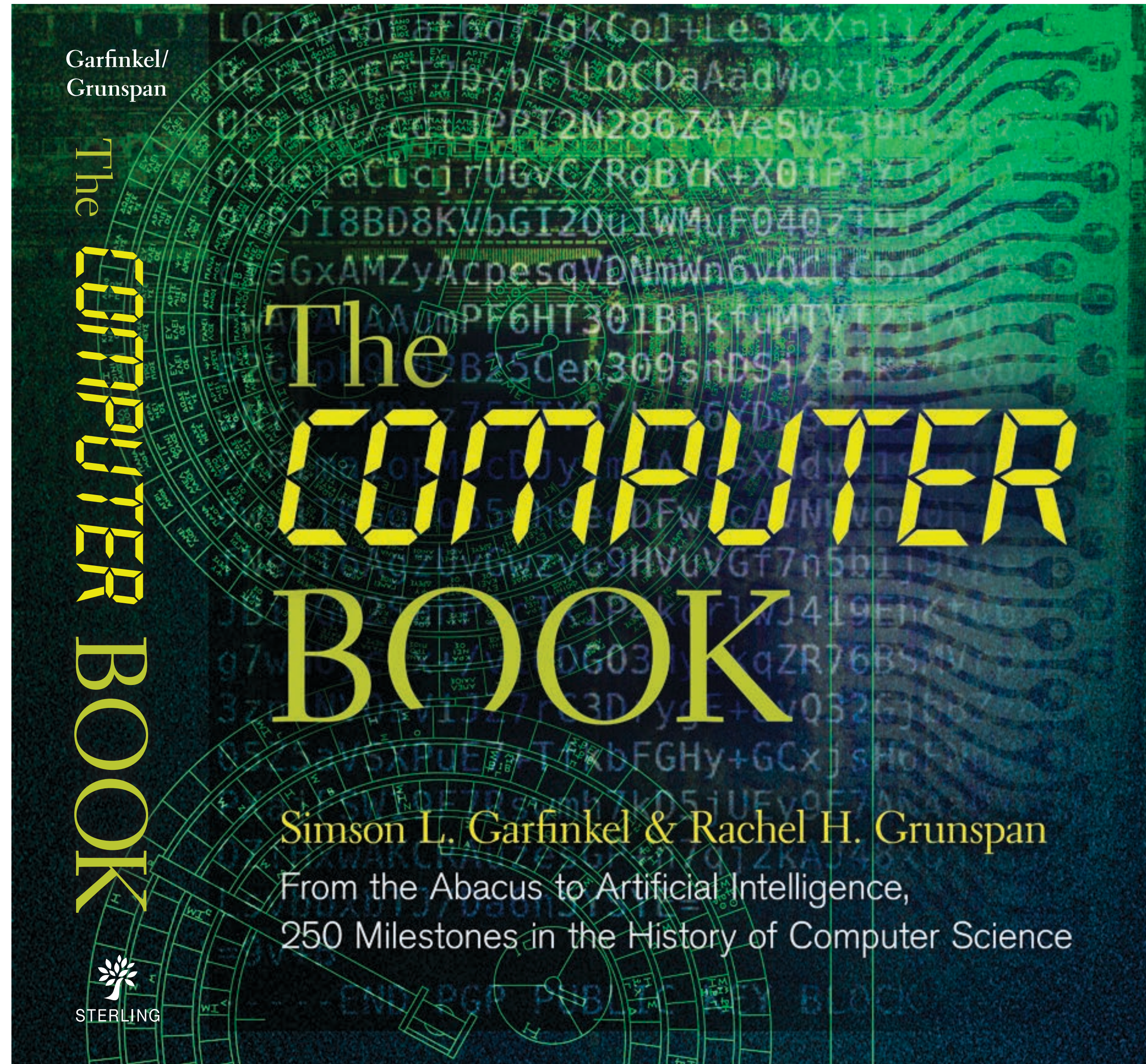
Observing the impact of research by writing *The Computer Book*

Simson L. Garfinkel

November 19, 2019

National Science Foundation

Note: Any views expressed on the issues are those of
the author and not those of the U.S. Census Bureau.



The Computer Book
Garfinkel and Grunspan,
Sterling Milestones, 2018

Outline for this talk

1. Author background
2. Project genesis
3. Researching the milestones
4. Writing Tech and Production
5. Questions & Answers

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1

Author Background



Instrumentation Research
Weizmann Institute of Science
Summer 1986

Science writer, entrepreneur & academic

1987 — SB, Massachusetts Institute of Technology

1988 — MS, Columbia University School of Journalism

1988–2002 — Freelance writer, computer consultant, entrepreneur

2005 — PhD Massachusetts Institute of Technology

2007–2014 — Naval Postgraduate School



2015–2016 — NIST



2017– — US Census Bureau





2

Project Genesis

June 2, 2016 — Email from Matt Wagner, Fresh Books

Want to write a book?

From: Matt Wagner matt@fresh-books.com
Subject: Book for Sterling
Date: June 2, 2016 at 3:54 PM
To: simsong@acm.org



Hi Simson,

I hope you're well. I thought of you when I received this query from Sterling, an imprint owned by B&N. I've been doing a few reference and education titles with this editor and it looks like she wants to do something about milestones in computer science. Now, I can get more info if this sounds of interest but in the past she has seemed to be pretty open to what someone might bring to the table.

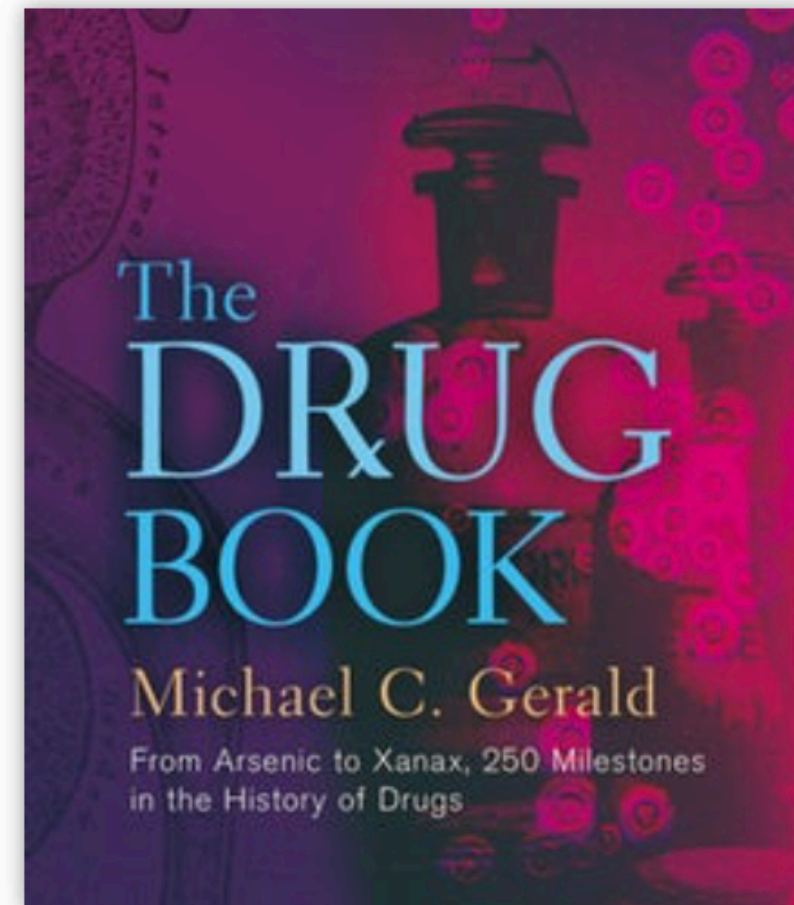
The likely advance for this is tops, but since it would be with Sterling you're pretty much guaranteed to be stocked at B&N, which is no sure thing these days. Let me know if you feel like doing a book :-). They have generally more trade-like (longer) schedules, so I'd guess it's a project that could be done over 9-12 months -

Begin forwarded message:

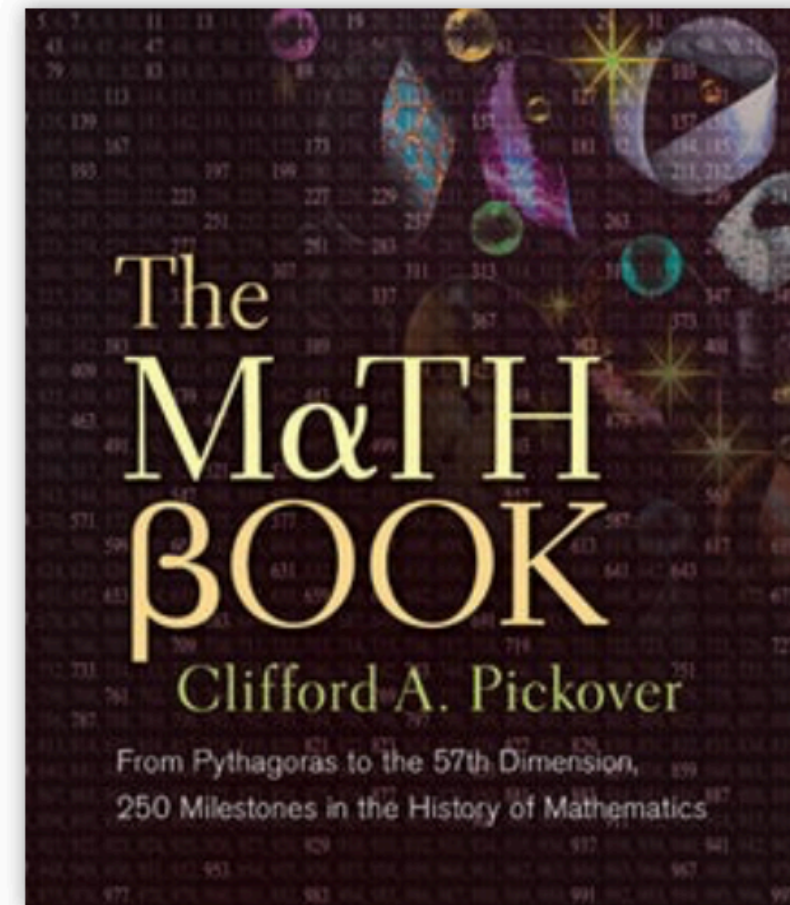
By the way, do any of the authors you work with have experience or interest in a book that recounts milestones in the history of computer science? Preferably someone with a pretty good platform or standing in the computer science community? (I'm open to the author-coauthor arrangement as well.)

The Sterling “Milestones” Series

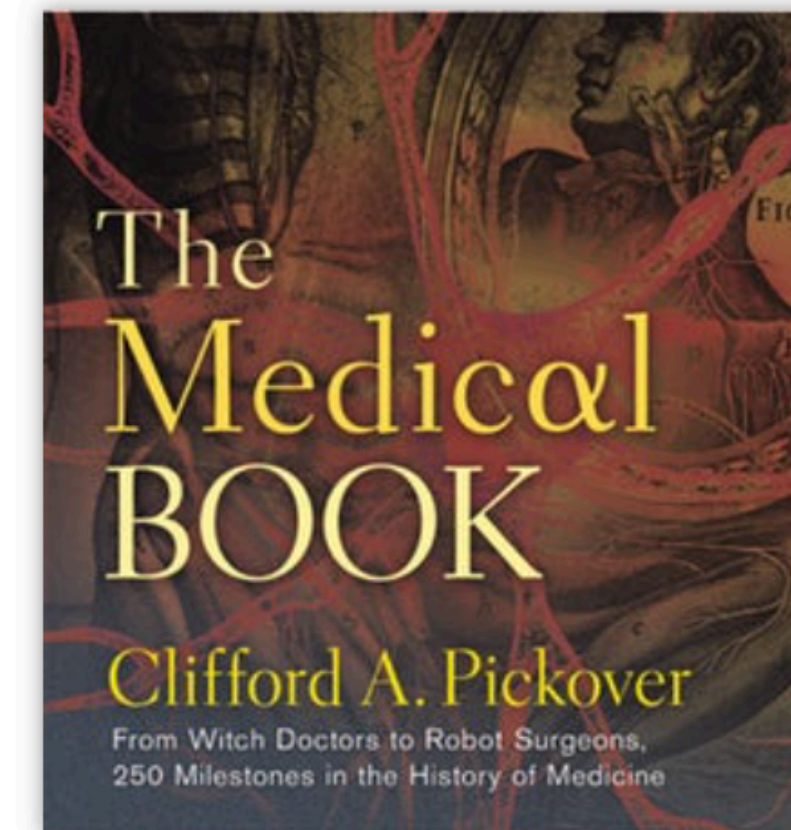
The Physics Book, Clifford Pickover, 2011



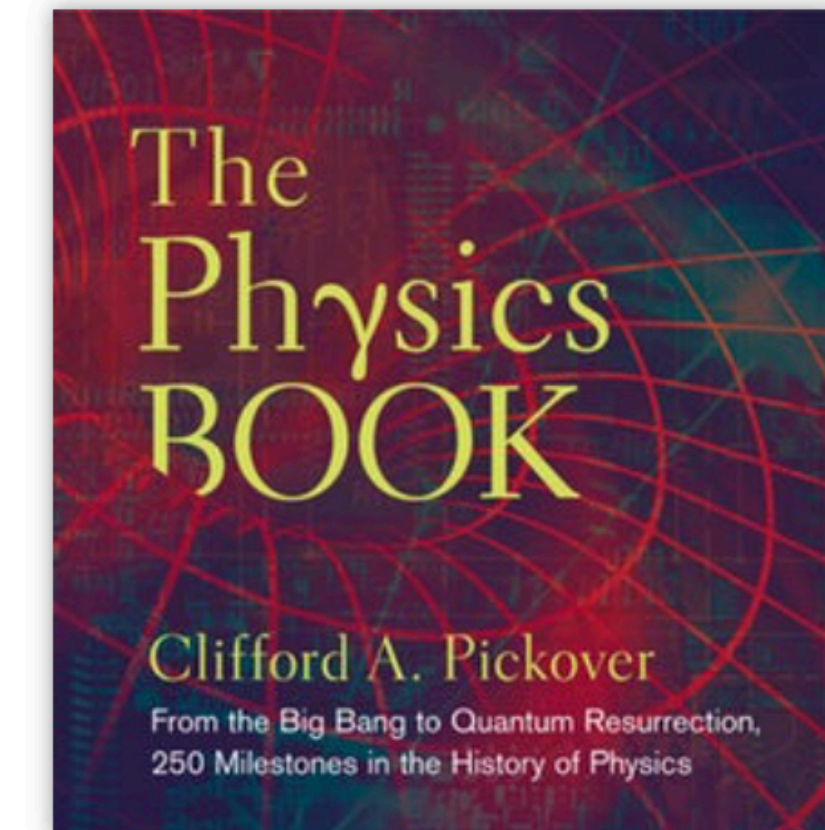
The Drug Book
Michael C. Gerald



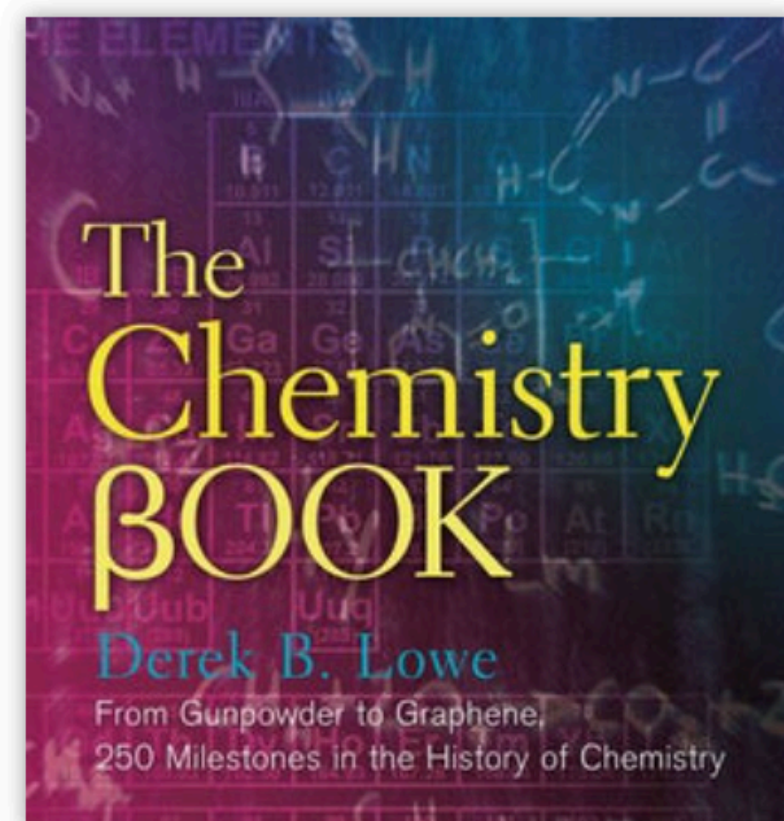
The Math Book
Clifford A. Pickover



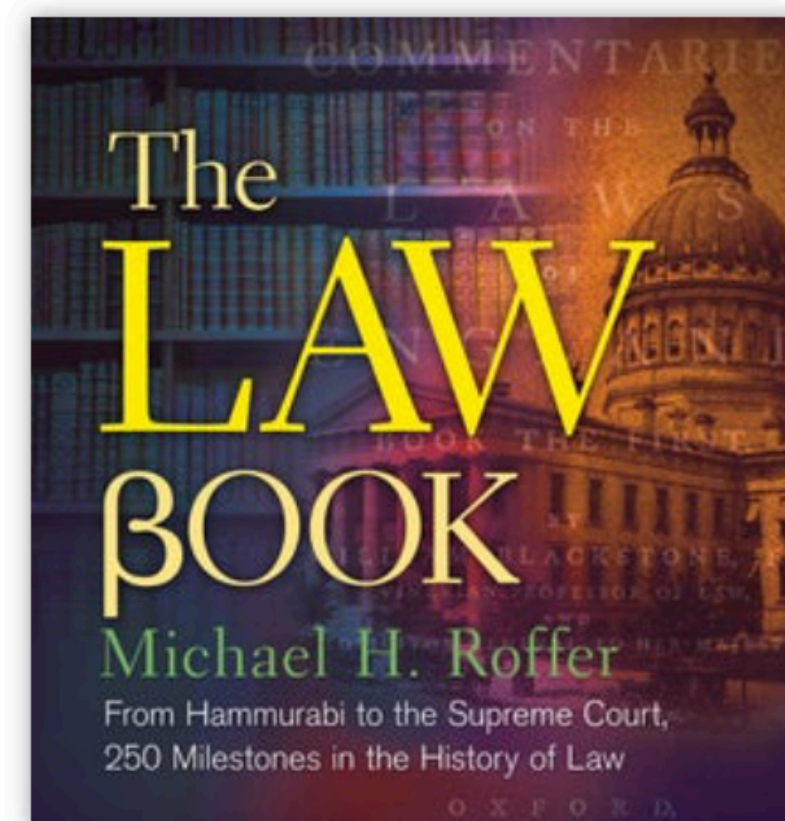
The Medical Book
Clifford A. Pickover



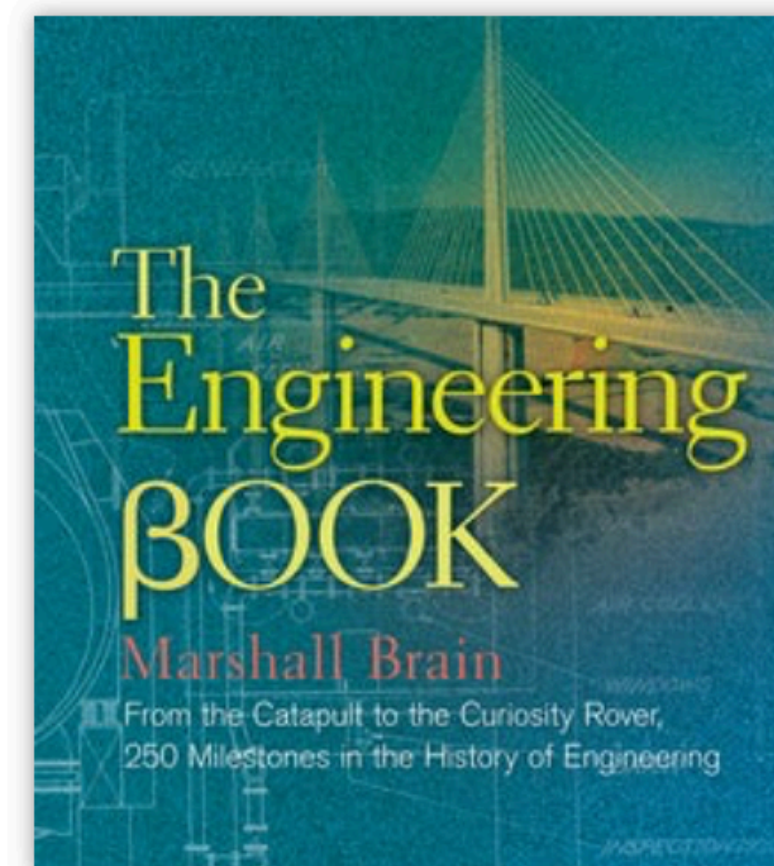
The Physics Book
Clifford A. Pickover



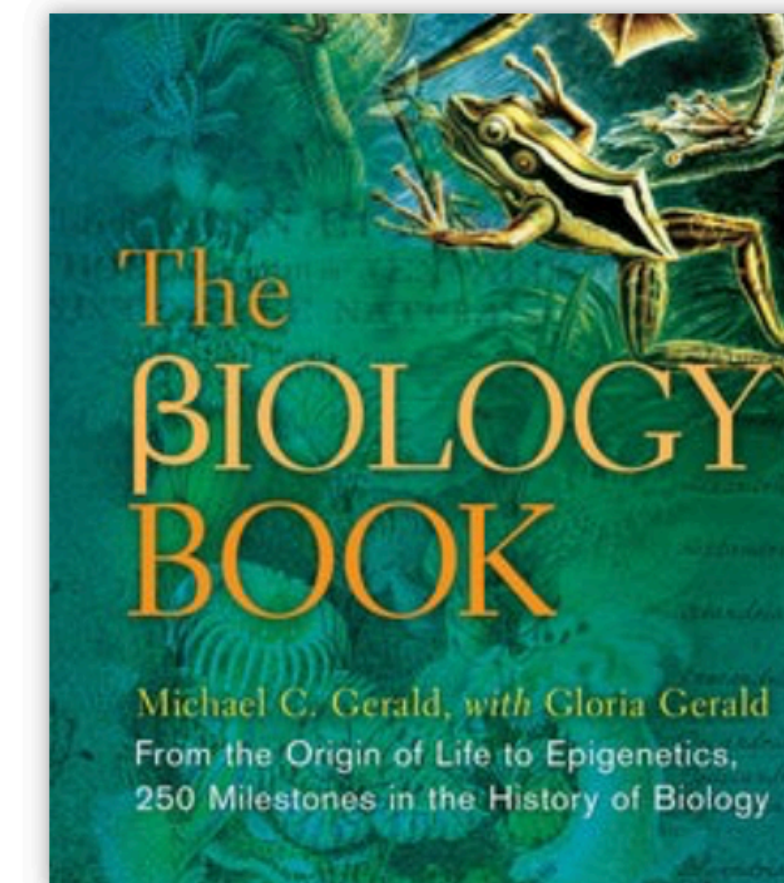
The Chemistry Book
Derek B Lowe



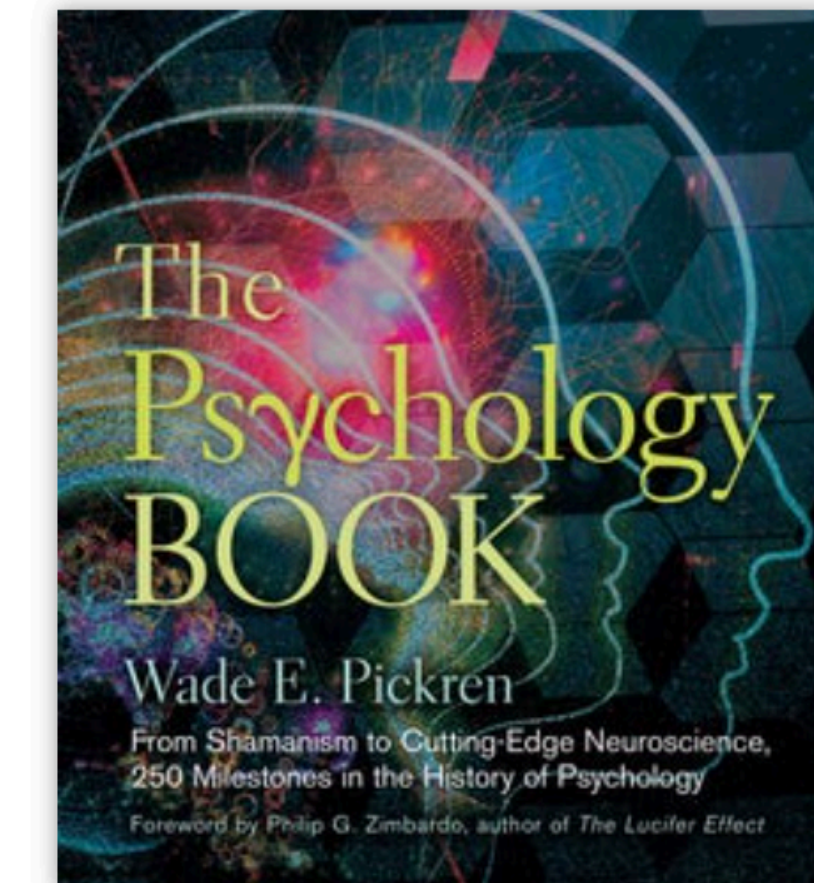
The Law Book
Michael H. Roffer



The Engineering Book
Marshall Brain

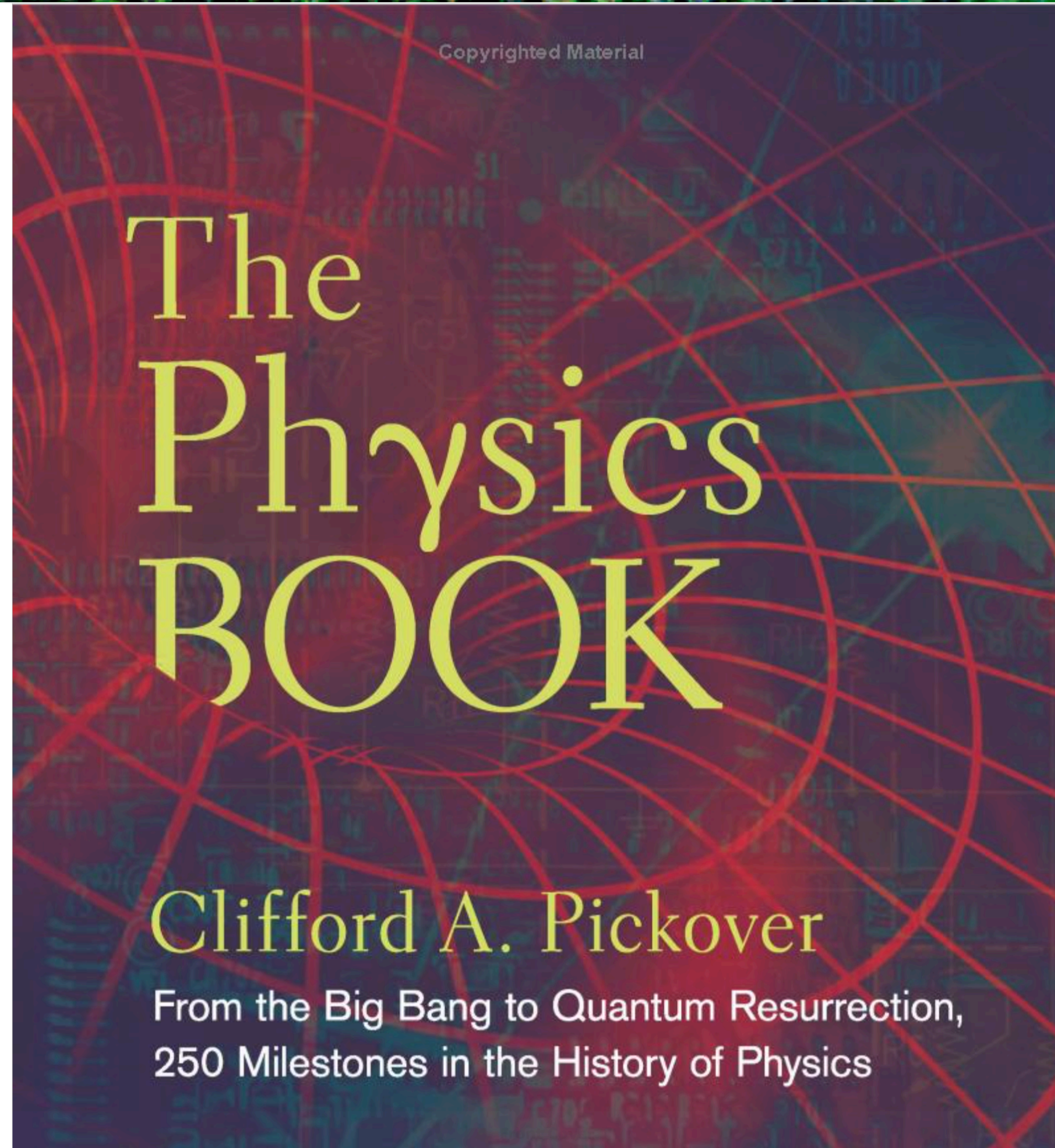


The Biology Book
Michael C. Gerald, Gloria E. Gerald



The Psychology Book
Wade E. Pickren, Philip G. Zimbardo

So we order *The Physics Book* and check it out



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Big Bang

Georges Lemaître (1894–1966), Edwin Hubble (1889–1953),
Fred Hoyle (1915–2001)

In the early 1930s, Belgian priest and physicist Georges Lemaître proposed what became known as the Big Bang theory, according to which our universe evolved from an extremely dense and hot state, and space has been expanding ever since. The Big Bang is believed to have occurred 13.7 billion years ago, and today most galaxies are still flying apart from one another. It is important to understand that galaxies are not like the flying debris from a bomb that has just exploded. Space itself is expanding. The distances between galaxies are increasing in a way that is reminiscent of black dots painted on the surface of a balloon that move away from one another when the balloon is inflated. It doesn't matter on which dot you reside in order to observe this expansion. Looking out from any dot, the other dots appear to be receding.

Astronomers who examine distant galaxies can directly observe this expansion, originally detected by U.S. astronomer Edwin Hubble in the 1920s. Fred Hoyle coined the term *Big Bang* during a 1949 radio broadcast. Not until about 400,000 years after the Big Bang did the universe cool sufficiently to permit protons and electrons to combine to form neutral hydrogen. The Big Bang created helium nuclei and the light elements in the first few minutes of the universe's existence, providing some raw material for the first generation of stars.



Marcus Chown, author of *The Magic Furnace*, suggests that soon after the Big Bang, clumps of gas began to congeal, and then the universe began to light up like a Christmas tree. These stars lived and died before our galaxy came into existence.

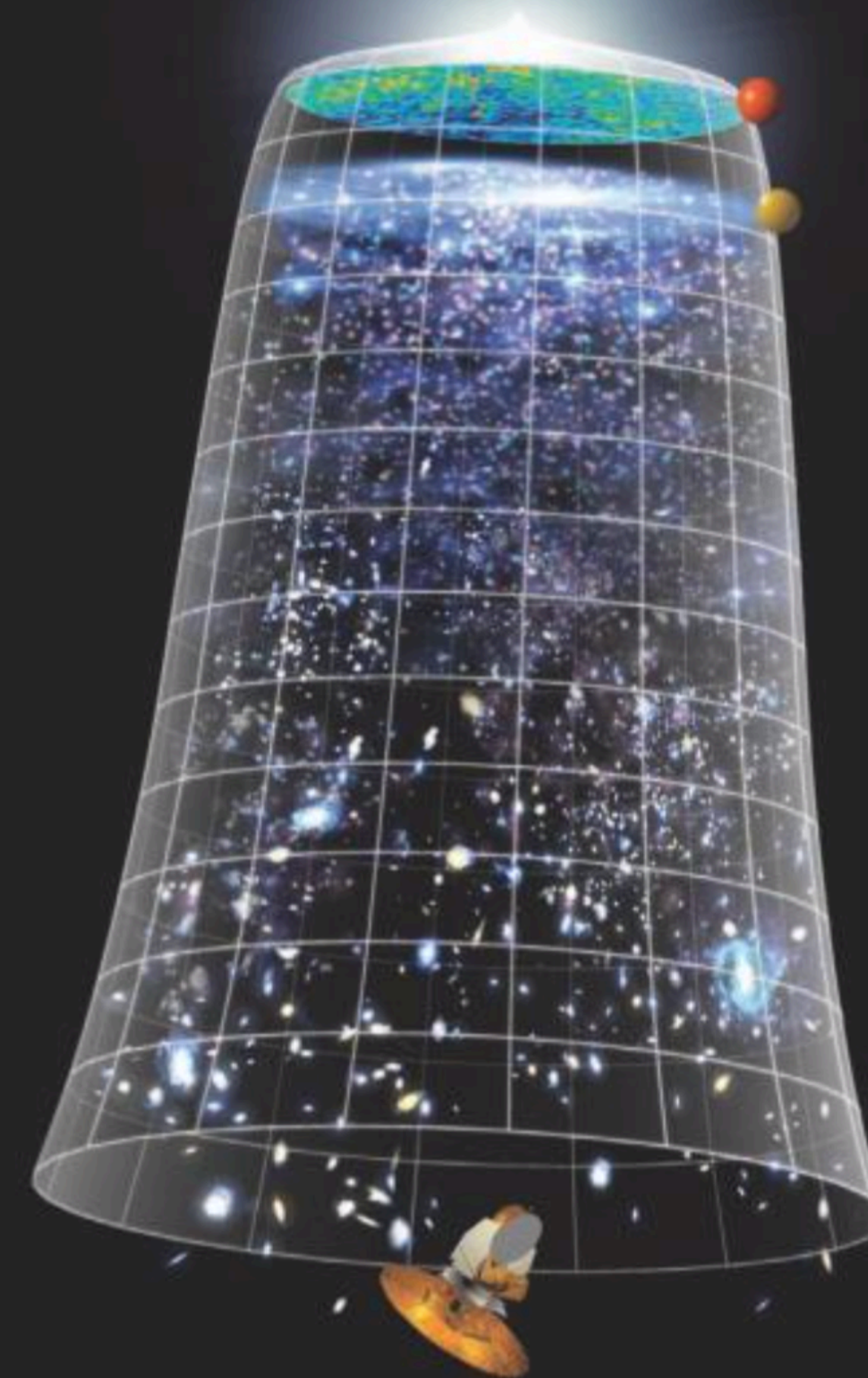
Astrophysicist Stephen Hawking has estimated that if the rate of the universe's expansion one second after the Big Bang had been smaller by even one part in a hundred thousand million million, the universe would have re-collapsed and no intelligent life could have evolved.

SEE ALSO Olbers' Paradox (1823), Hubble's Law of Cosmic Expansion (1929), CP Violation (1964), Cosmic Microwave Background (1965), Cosmic Inflation (1980), Hubble Telescope (1990), Cosmological Big Rip (36 Billion).

LEFT: According to ancient Finnish creation mythology, the heavens and the Earth were formed during the breaking of a bird's egg. RIGHT: Artist representation of the Big Bang (topmost point). Time proceeds down the page. The universe undergoes a rapid period of initial expansion (up to the red spherical marker). The first stars appear after about 400 million years (denoted by the yellow sphere).

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Avogadro's Gas Law

Amedeo Avogadro (1776–1856)

Avogadro's Law, named after Italian physicist Amedeo Avogadro who proposed it in 1811, states that equal volumes of gases at the same temperature and pressure contain the same number of molecules, regardless of the molecular makeup of the gas. The law assumes that the gas particles are acting in an "ideal" manner, which is a valid assumption for most gases at pressures at or below a few atmospheres, near room temperature.

A variant of the law, also attributed to Avogadro, states that the volume of a gas is directly proportional to the number of molecules of the gas. This is represented by the formula $V = a \times N$, where a is a constant, V is the volume of the gas, and N is the number of gas molecules. Other contemporary scientists believed that such a proportionality should be true, but Avogadro's Law went further than competing theories because Avogadro essentially defined a molecule as the smallest characteristic particle of a substance—a particle that could be composed of several atoms. For example, he proposed that a water molecule consisted of two hydrogen atoms and one oxygen atom.

Avogadro's number, 6.0221367×10^{23} , is the number of atoms found in one mole of an element. Today we define Avogadro's number as the number of carbon-12 atoms in 12 grams of unbound carbon-12. A mole is the amount of an element that contains precisely the same number of grams as the value of the atomic weight of the substance. For example, nickel has an atomic weight of 58.6934, so there are 58.6934 grams in a mole of nickel.

Because atoms and molecules are so small, the magnitude of Avogadro's number is difficult to visualize. If an alien were to descend from the sky to deposit an Avogadro's number of unpopped popcorn kernels on the Earth, the alien could cover the United States of America with the kernels to a depth of over nine miles.

SEE ALSO Charles' Gas Law (1787), Atomic Theory (1808), Kinetic Theory (1859).

Place 24 numbered golden balls (numbered 1 through 24) in a bowl. If you randomly drew them out one at a time, the probability of removing them in numerical order is about 1 chance in Avogadro's number—a very small chance!

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Timeline

2016

- June 2 — Initial email
- June - Aug — Publisher wants proposal with 50 milestones, 5 fully written, and co-author
- Aug — term-sheet and contract. **Delivery date: November 2017**
- Aug—March — Contract negotiations

2017

- March — New co-author
- April 12 — New contract, **same delivery dates (November 2017)**

Co-author Rachel Grunspan (Approved Bio)

Rachel H. Grunspan has worn many hats in her almost 20 years at the CIA including cyber-threat analyst, game and simulation designer, and a leader in the world of digital innovation. She is a member of the Senior Intelligence Service and a winner of the 2007 Director of National Intelligence Galileo Award. Rachel received a BA in Politics from Brandeis University and a Master of Science in Information Systems from the London School of Economics and Political Science.



Delivery Dates as of April 12, 2017

| | |
|-----------------------------------|---------------------------|
| Complete table of Contents | May 30, 2017 |
| 20% of Manuscript | July 15, 2017 |
| 60% of the manuscript | September 14, 2017 |
| Complete work | November 13, 2017 |

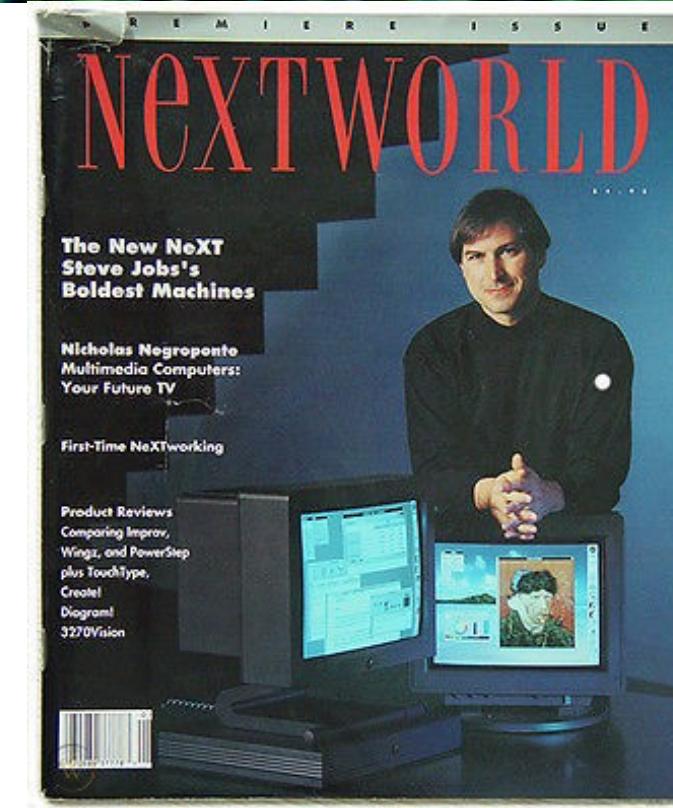
The background features a dark blue field with intricate, wavy, greenish-yellow patterns that resemble ripples or a textured surface. A large, bold, yellow number '3' is centered in the upper half of the image.

3

Researching the Milestones

Where does one start?

How do you separate a personal history from the history of a discipline?



Step 1: Build an initial list of milestones

Step 1 — Brain storming

Step 2 — Other lists

ACM Turing Award Winners (50th celebration was 2016)

Wizards and their Wonders: Portraits in Computing

Christopher Morgan & Louis Fabian Bachrach

https://en.wikipedia.org/wiki/List_of_pioneers_in_computer_science

IEEE Computing History timeline

<https://ieeecs-media.computer.org/assets/pdf/timeline.pdf>

<https://history.computer.org/pubs/timeline.pdf>

Computer History Museum timeline

<https://www.computerhistory.org/timeline/>

Centre for Computing History timeline

<http://www.computinghistory.org.uk/cgi/computing-timeline.pl>

MIT Laboratory for Computing Science Timeline (LCS 35 book)



Ireas Bechtolsheim, Gordon Bell, Gwen Bell, Eric Be
och, Leonard Bosack, Jeff Braun, Dan Bricklin, Fred
Catmull, Vint Cerf, John Chambers, John Chownin
k, Fernando Corbató, Joel Birnbaum, Jim Blinn, Er
ll, Whitfield Diffie, John Doerr, Esther Dyson, Presp
Gordon Eubanks, Jr. **Wizards** Robert Evans, Robe
o, Jay Forrester, William Foster **and** Bob Frankston.
William Gates **Their** Louis Gerstner, Charles Gesc
Heilmeier, Andrew Heller **Wonders** Gardner Hend
F, Grace Murray Hopper, Max Hopper, Charles Hou
hn, Philippe Kahn, Jerrold Kaplan, Mitchell Kapor,
la, Steven Kirsch, Leonard Kleinrock, Donald Knuth
renda Laurel, David Liddle, Robert Lucky, Dan Lync
hardt, Max Matthews, John Mauchly, John McCarthy
ealy, Carver Mead **Portraits** William Melton, Rob
yhrvold Nicholas Negroponte **in** Allen Newell, Ken
eymour Papert **Computing** Suhas Patil, David Pat
Rick Rashid, Justin Rattner, Raj Reddy, Dennis Rite
oizen, Benjamin Rosen, Harry Saal, Pamela Samuels
Richard Shaffer, John Shoch, Edward Shortliffe, Herb
in, Gary Starkweather, Ray Stata, George Stibitz, Mic
hard Tennant, Dorothy Terrell, Ken Thompson, Jose
hn von Neumann, Steven Walske, Charles Wang, Jol
hite, Ann Winblad, Steve Wozniak, William Wulf, Jo

250 Milestones by November 15

| | |
|--|--------------|
| Milestones on contract signing: | 350 |
| Milestones added during research: | ≈ 50 |
| Milestones removed | ≈ 150 |

Diversity Goals and Regrets

We tried to balance:

Women

Continents

Countries

Fields

Cultural

Original inclusion metric

stuff that I knew about.

This didn't work out so well.

Revised: Notability

“Firsts.”

Cultural significance beyond computing.

Regrets:

Africa, South America, China

Critical question: balancing diversity and historical authenticity

Expanded Inclusion Criteria:

We wanted milestones that told a story

Led to the creating of thinking machines

Show the step-by-step progression from early devices for manipulating information to the pervasive society of machines and people that surrounds us today.

Document the results of the integration of computers into societys.

Important “firsts,” from which other milestones cascaded or from which important developments derive.

Resonate with the general public so strongly that they influenced behavior or thinking. (e.g. HAL 9000)

On the critical path of current capabilities, belifs, or application of computers and associated technologies (e.g. invention of the integrated circuit)

Likely to be building block for future milestones (e.g. DNA for strage)

Milestones yet to occur

How does one characterize the range of computer science?

The traditional approach is by discipline

Architecture
Artificial Intelligence
Business and Industry
Cryptography
Culture, Entertainment and Games
Hardware
Information
Microcomputers
Physics
Quantum Computing

Robotics
Semiconductors
Software
Storage
Theory

**We used these
categories for assuring
coverage and diversity,
but we did not reveal
them to the reader**

- ✓ Artificial Intelligence
- ✓ Book
- ✓ Business
- ✓ Cryptography
- ✓ Culture
- ✓ Entertainment
- ✓ Games
- ✓ Gaming
- ✓ Hardware
- ✓ Industry
- ✓ Information
- ✓ Invention
- ✓ Micros
- ✓ Networking
- ✓ Physics
- ✓ Popular Culture
- ✓ Quantum Computing
- ✓ Robotics
- ✓ Semiconductors

Instead, we used the history of computing to tell the history technology.

Computing has been with us since the dawn of civilization

(Yuval Noah Harari makes this same point in *Sapiens*.)

Developments in computing are intimately connected to developments in science and technology

Each development in computing sets the stage for the next development

We see computing developments as fitting into six specific eras.

Human Computation

1758

Human Computers Predict Halley’s Comet

Edmond Halley (1656–1742), Alexis-Claude Clairaut (1713–1765), Joseph Jérôme Lalande (1732–1807), Nicole-Reine Lepaute (1723–1788)

The discovery of Kepler’s laws of planetary motion and Isaac Newton’s more general laws of motion and gravity encouraged scientists to seek elegant mathematical models to describe the world around them. Edmond Halley, the editor of Newton’s *Principia* (1687), used Newton’s calculus and laws to show that a comet seen in the night sky in 1531 and 1682 must be the same object. Halley’s work depended on the fact that the comet’s orbit was influenced not just by the sun, but also by the other planets in the solar system—especially Jupiter and Saturn. But Halley could not come up with an exact set of equations to describe the comet’s trajectory.

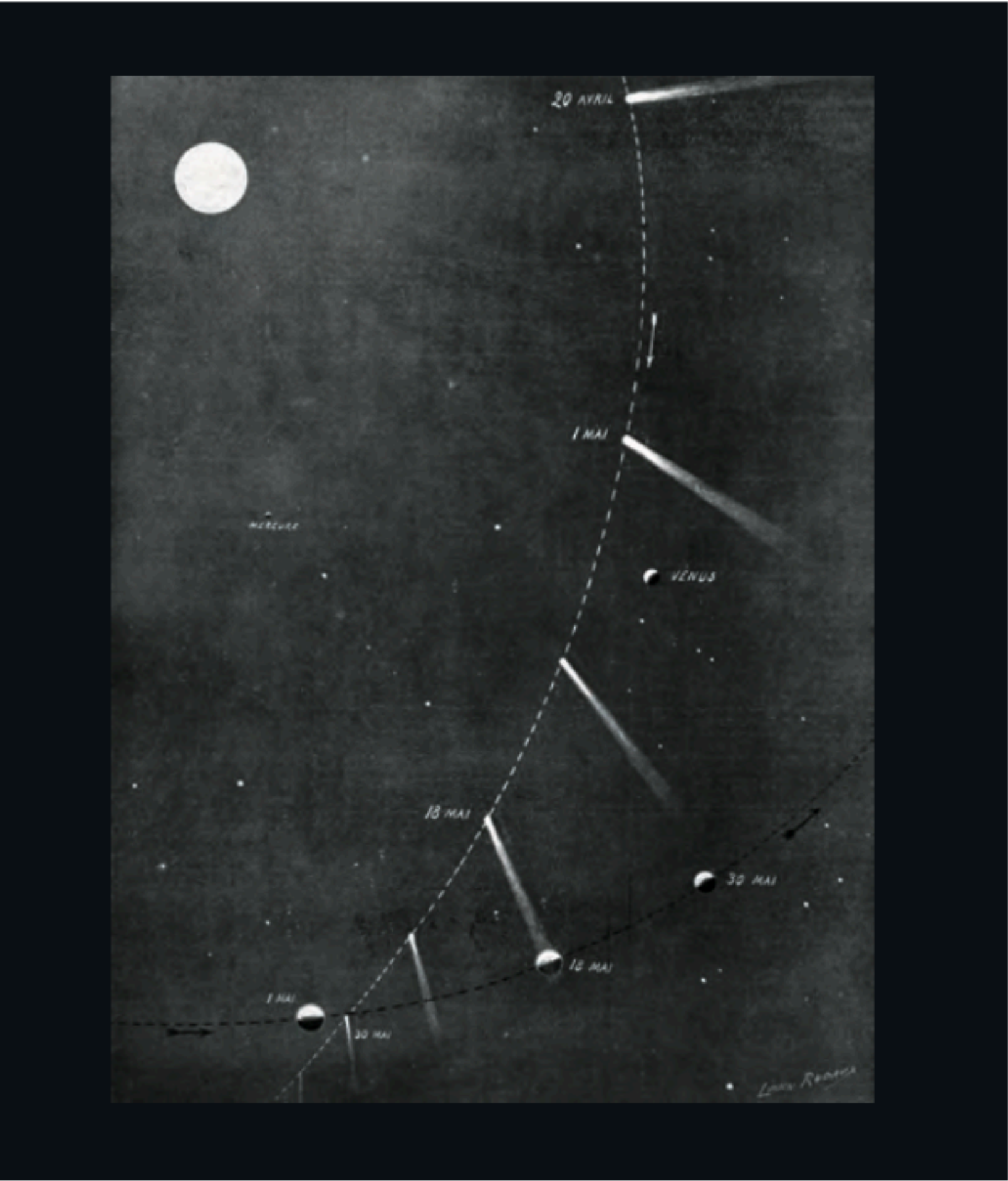
Alexis-Claude Clairaut was a French mathematician who devised a clever solution to the problem. But it wasn’t mathematically elegant: instead of solving the problem symbolically, his method solved the problem numerically—that is, with a series of arithmetic calculations. He worked with two friends, Joseph Jérôme Lalande and Nicole-Reine Lepaute, during the summer of 1758, and the three systematically plotted the course of the comet, calculating the wanderer’s return to within 31 days.

This approach of using numerical calculations to solve hard science problems quickly caught on. In 1759, Lalande and Lepaute were hired by the French Académie des Sciences to contribute computations to the *Connaissance des Temps*, the official French almanac; five years later, the English government hired six human computers to create its own almanac. These printed tables charted the anticipated positions of the stars and planets and were the basis of celestial navigation, allowing the European powers to build out their colonies.

In 1791, Gaspard Clair François Marie Riche de Prony (1755–1839) embarked on the largest human computation project to that date: to create a 19-volume set of trigonometric and logarithmic tables for the French government. The project took six years and required 96 human computers.

SEE ALSO First Recorded Use of the Word Computer (1613)

The course of Halley’s Comet across the night sky from April through May of 1910.



We see computing developments as fitting into six specific eras.

Human Computation

Mechanical Calculations

1851

Thomas Arithmometer

Gottfried Wilhelm Leibniz (1646–1716),
Charles Xavier Thomas de Colmar (1785–1870)

German philosopher and mathematician Gottfried Leibniz became interested in mechanical calculation after seeing a pedometer while visiting Paris in 1672. He invented a new type of gear that could advance a 10-digit dial exactly 0 to 9 places, depending on the position of a lever, and used it in a machine with multiple dials and levers called the *stepped reckoner*. Designed to perform multiplication with repeated additions and division by repeated subtractions, the reckoner was hard to use because it didn't automatically perform carry operations; that is, adding 1 to 999 did not produce 1,000 in a single operation. Worse, the machine had a design flaw—a bug—that prevented it from working properly. Leibniz built only two of them.

More than 135 years later, Charles Xavier Thomas de Colmar left his position as inspector of supply for the French army and started an insurance company. Frustrated by the need to perform manual arithmetic, Thomas designed a machine to help with math. Thomas's arithmometer used Leibniz's mechanism, now called a *Leibniz wheel*, but combined it with other gears, cogs, and sliding levers to create a machine that could reliably add and subtract numbers up to three digits, and multiply and divide as well. Thomas patented the machine, but his business partners at the insurance firm were not interested in commercializing it.

Twenty years later, Thomas once again turned his attention to the arithmometer. He demonstrated a version at the 1844 French national exhibition and entered competitions again in 1849 and 1851. By 1851, he had simplified the machine's operation and extended its capabilities, giving it six sliders for setting numbers and 10 dials for display results. Aided by three decades' advance in manufacturing technology, Thomas was able to mass-produce his device. By the time of his death, his company had sold more than a thousand of the machines—the first practical calculator that could be used in an office setting—and Thomas was recognized for his genius in creating it. The size of the arithmometer was approximately 7 inches (18 centimeters) wide by 6 inches (15 centimeters) tall.

SEE ALSO Curta Calculator (1948)

This Thomas Arithmometer can multiply two 6-digit decimal numbers to produce a 12-digit number. It can also divide.



We see computing developments as fitting into six specific eras.

Human Computation
Mechanical Calculations
**Electric Communication
and Computation**
Relays, Telegraph, Teletype

1874

Baudot Code

Jean-Maurice-Émile Baudot (1845–1903), Donald Murray (1865–1945)

Early telegraph systems relied on human operators to encode and transmit the sender's message, and then to perceive, decode, and transcribe the message on paper upon receipt. Relying on human operators limited the maximum speed at which a message could be sent and required operator skills that were not easily available.

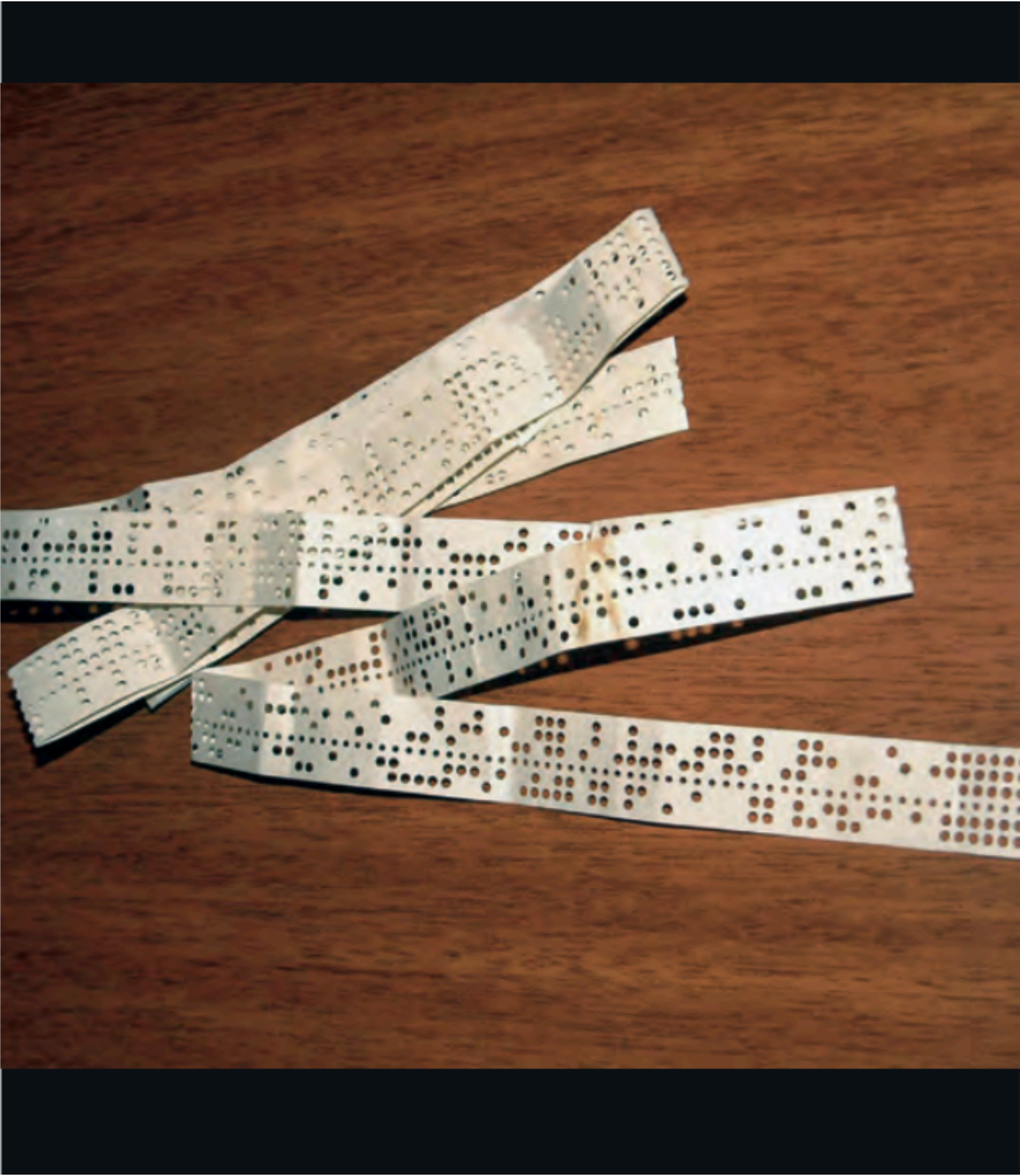
Émile Baudot developed a better approach. A trained French telegraph operator, Baudot devised a system that used a special keyboard with five keys (two for the left hand and three for the right) to send each character. Thirty-one different combinations arise from pressing one or more of the five keys together; Baudot assigned each code to a different letter of the alphabet. To send a message, the operator would type the codes in sequence as the machine clicked, roughly four times a second. With each click, a rotating part that Baudot called the *distributor* would read the position of each key in order and, if the key was pressed, send a corresponding pulse down the telegraph wire. At the other end, a remote printer would translate the codes back into a printed character on a piece of paper tape.

Baudot was one of the first people to combine key inventions by others into one working system. He patented his invention in 1874, started selling devices to the French Telegraph Administration in 1875, and was awarded the gold medal at the Paris Exposition Universelle in 1878. Baudot's code was adopted as the International Telegraph Alphabet No. 1 (ITA1), one of the original international telecommunications standards. In recognition of his contribution, the baud, a unit of data transmission speed equal to the number of signal changes per second, is named after him.

In 1897, the Baudot system expanded to incorporate punched paper tape. The keyboard was disconnected from the telegraph line and connected to a new device that could punch holes across a strip of paper tape, with one hole corresponding to each key. Once punched, the tape could be loaded into a reader and the message sent down the telegraph wire faster than a human could type. In 1901, the inventor Donald Murray developed an easier-to-use punch that was based on a typewriter keyboard. Murray also made changes to Baudot's code; the resulting code was known as the Baudot-Murray code (ITA2) and remained in use for more than 50 years.

SEE ALSO ASCII (1963), Unicode (1992)

Paper tape punched with the five-level Baudot code. The large holes correspond to the 5 bits of the code, while a rotating toothed tractor wheel fit into the small holes and used them to pull the tape through the machine.



We see computing developments as fitting into six specific eras.

- Human Computation
- Mechanical Calculations
- Electric Communication and Computation
- Electronic Computation**

1943

ENIAC

John Mauchly (1907–1980), J. Presper Eckert (1919–1995)

ENIAC was the first *electronic* computer, which means it computed with tubes rather than relays. Designed by John Mauchly and J. Presper Eckert at the Moore School of Electrical Engineering at the University of Pennsylvania, ENIAC had 17,468 vacuum tubes, was 8 feet (2.4 meters) high by 3 feet (0.9 meters) deep by 100 feet (30.5 meters) long, and weighed more than 30 tons.

ENIAC had an IBM punch-card reader for input and a card punch for output, but the machine had no memory for data or programs. Instead, numbers under calculation were kept in one of the computer's 20 accumulators, each of which could store 10 decimal digits and perform addition or subtraction. Other hardware could perform multiplication, division, and even square roots. ENIAC wasn't programmed in today's sense. Instead, a set of panels had 1,200 10-position rotary switches that would energize different circuits in a specific sequence, causing electronic representations of numbers to flow through different parts of the machine at predetermined times, and leading the machine computation to take place.

ENIAC was built to perform complex ballistics calculations for the US Army, but John von Neumann (1903–1957) at the Manhattan Project learned about ENIAC, so the machine's first official use was actually to perform computations for the development of the hydrogen bomb.

Ironically, the men who built the hardware never considered the need for, or the complexity of, programming the machine. They left the job of making the machine actually calculate to six human computers: Frances "Betty" Snyder Holberton (1917–2001), Betty "Jean" Jennings Bartik (1924–2011), Kathleen McNulty Mauchly Antonelli (1921–2006), Marlyn Wescoff Meltzer (1922–2008), Ruth Lichterman Teitelbaum (1924–1986), and Frances Bilas Spence (1922–2012).

Those women, some of the world's first programmers, had to devise and then debug their own algorithms. But the women were not acknowledged in their own time. In 2014, Kathy Kleiman produced the documentary *The Computers*, which finally told the women's story.

SEE ALSO First Recorded Use of the Word *Computer* (1613), EDVAC First Draft Report (1945)

ENIAC, the first electronic computer, was built to perform calculations for the US Army. Pictured operating the machine are Corporal Irwin Goldstein, Private First Class Homer Spence, Betty Jean Jennings, and Frances Bilas.



We see computing developments as fitting into six specific eras.

Human Computation

Mechanical Calculations

Electric Communication
and Computation

Electronic Computation

Solid State Computing

1874

Semiconductor Diode

Michael Faraday (1791–1867), Karl Ferdinand Braun (1850–1918)

Semiconductors are curious devices: not quite conductors like copper, gold, or silver, not quite insulators like plastic or rubber. In 1833, Michael Faraday discovered that the chemical silver sulfide became a better conductor when heated, unlike metals that lose their conductivity under the same conditions. Separately, in 1874, Karl Ferdinand Braun, a 24-year-old German physicist, discovered that a metal sulfide crystal touched with a metal probe would conduct electricity in only one direction. This “one direction” characteristic is what defines *diodes* or *rectifiers*, the simplest electronic components.

Braun’s discovery was a curiosity until the invention of radio. The diode proved critical in allowing radio to make the transition from wireless telegraphy to the transmission and reception of the human voice. The diode of choice for these early radio sets was frequently called a *cat’s whisker diode*, because it consisted of a crystal of galena, a form of lead sulfide, in contact with a spring of metal (the “whisker”). By carefully manipulating the pressure and orientation of the metal against the crystal, an operator could adjust the electrical properties of the semiconductor until they were optimal for radio reception. Powered only by the radio waves themselves, a crystal set was only strong enough to faintly produce sounds in an earphone.

Crystal radio receivers were used onboard ships and then in homes until they were replaced by new receivers based on vacuum tubes, which could amplify the faint radio waves so that they were strong enough to power a speaker and fill a room with speech or music. But tubes didn’t mark the end of the crystal radio: the devices remained popular for people who couldn’t get tubes—such as on the front lines in World War II—as well as among children learning about electronics. In the 1940s, scientists at Bell Labs turned their attention to semiconductor radios once again in an effort to perfect microwave communications. In the process, they discovered the transistor.

Braun went on to make other fundamental contributions to physics and electronics. In 1897, he invented the cathode-ray tube, which would become the basis of television. He shared the 1909 Nobel Prize with Guglielmo Marconi (1874–1937) “in recognition of their contributions to the development of wireless telegraphy.”

SEE ALSO Silicon Transistor (1947)

Crystal Detector, made by the Philmore Manufacturing Company. To use this device, the operator would connect a wire to each of the two flanges and press the metal “whisker” into the semiconductor crystal.



We see computing developments as fitting into six specific eras.

Human Computation

Mechanical Calculations

Electric Communication
and Computation

Electronic Computation

Solid State Computing

Parallel Computing

2006

Hadoop Makes Big Data Possible

Doug Cutting (dates unavailable)

Parallelism is the key to computing with massive data: break a problem into many small pieces and attack them all at the same time, each with a different computer. But until the early 2000s, most large-scale parallel systems were based on the scientific computing model: they were one-of-a-kind, high-performance clusters built with expensive, high-reliability components. Hard to program, these systems mostly ran custom software to solve problems such as simulating nuclear-weapon explosions.

Hadoop takes a different approach. Instead of specialty hardware, Hadoop lets corporations, schools, and even individual users build parallel processing systems from ordinary computers. Multiple copies of the data are distributed across multiple hard drives in different computers; if one drive or system fails, Hadoop replicates one of the other copies. Instead of moving large amounts of data over a network to super-fast CPUs, Hadoop moves a copy of the program to the data.

Hadoop got its start at the Internet Archive, where Doug Cutting was developing an internet search engine. A few years into the project, Cutting came across a pair of academic papers from Google, one describing the distributed file system that Google had created for storing data in its massive clusters, and the other describing Google's MapReduce system for sending distributed programs to the data. Realizing that Google's approach was better than his, he rewrote his code to match Google's design.

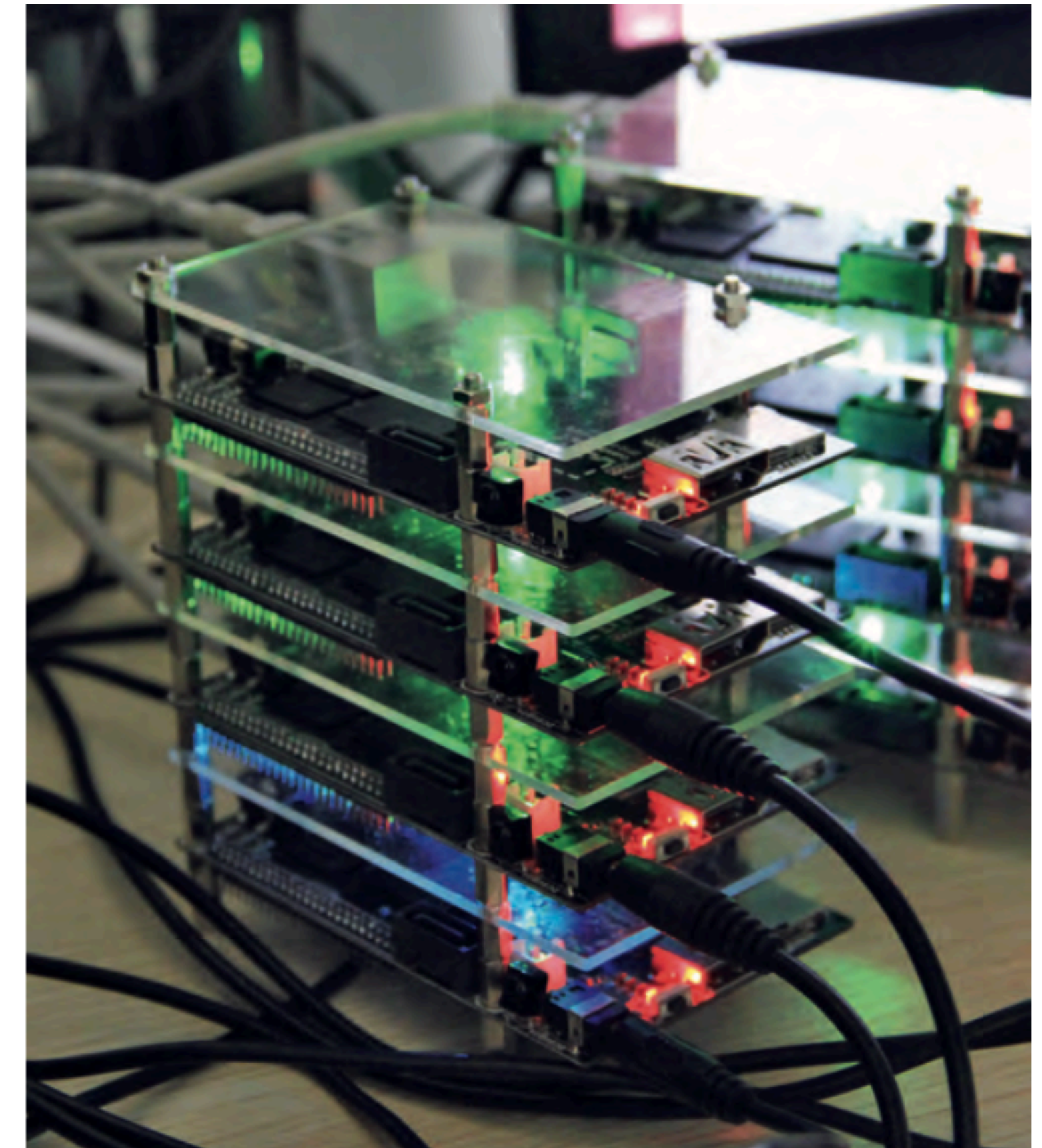
In 2006, Cutting recognized that his implementation of the distribution systems could be used for more than running a search engine, so he took 11,000 lines of code out of his system and made them a standalone system. He named it "Hadoop" after one of his son's toys, a stuffed elephant.

Because the Hadoop code was open source, other companies and individuals could work on it as well. And with the "big data" boom, many needed what Hadoop offered. The code improved, and the systems' capabilities expanded. By 2015, the open source Hadoop market was valued at \$6 billion and estimated to grow to \$20 billion by 2020.

SEE ALSO Connection Machine (1985), GNU Manifesto (1985),

Although the big-data program Hadoop is typically run on high-performance clusters, hobbyists have also run it, as a hack, on tiny underpowered machines like these Cubieboards.

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We see computing developments as fitting into six specific eras.

Human Computation

Mechanical Calculations

Electric Communication
and Computation

Electronic Computation

Solid State Computing

Parallel Computing

Artificial Intelligence

1997

Computer Is World Chess Champion

Garry Kasparov (b. 1963)

Ever since Alan Turing wrote the first computer chess program in 1950, computer scientists (and the general public) had viewed proficiency at chess as a litmus test for machines' intelligence. Machines, the thinking went, would be truly intelligent if they could beat a human at chess. When that happened, the challenge then subtly changed: would computers ever be able to beat *every human* at chess, even a grand master?

That happened nearly 50 years later in 1996, when IBM's Deep Blue computer beat world chess champion Garry Kasparov.

Kasparov and Deep Blue played two matches—the first took place in February 1996 in Philadelphia. Kasparov lost two games to Deep Blue but still won the match. The rematch occurred a year later in May 1997, when Kasparov lost to Deep Blue with a final score of 3.5 to 2.5 (one game was a draw). In an unusual twist, Deep Blue made an unexpected play during game two of the second match, rattling Kasparov and throwing him off his strategy. Kasparov did not know what to make of the move and considered it a sign of superior intelligence. While counterintuitive, Kasparov's interpretation of Deep Blue's capabilities highlights the power and weakness of relying on human intuition when playing games of skill.

In fact, Deep Blue's advantage was brute force, pure and simple. Deep Blue was really a massively parallel program coded in C, running on a UNIX cluster, and capable of computing 200 million possible board positions each second. Deep Blue's "evaluative function," which decided which board positions were better, was based on assessing four human-programmed variables: *material*, the value of each piece; *position*, the number of squares that buffer a player's piece from attack; *king safety*, a number that represents how safe the king is, given his location on the board and the position of the other pieces; and *tempo*, the success of a player advancing his or her position over time. Given these factors and the relatively constrained size of the board, chess became a "quantifiable" equation for Deep Blue. As such, the computer can win by simply seeking the best board positions—something it can do faster, and better, than any human.

SEE ALSO Computer Beats Master at Go (2016)

Viewers watch world chess champion Garry Kasparov on a television monitor at the start of the sixth and final match against IBM's Deep Blue computer in New York.

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Each of these areas covers different milestones

Artificial Intelligence dominates the dream of computing for centuries.

1770

The “Mechanical Turk”

Wolfgang von Kempelen (1734–1804)

After seeing an illusionist perform at Austria’s Schönbrunn Palace in 1770, Hungarian inventor Wolfgang von Kempelen told the Empress Maria Theresa of Austria that he could create something even better. The empress gave Kempelen six months to top the illusionist’s act.

The Industrial Revolution was well underway in 1770, and it was in this environment that Kempelen created an elaborate hoax that alleged to be a “thinking” machine. With expertise in hydraulics, physics, and mechanics, Kempelen returned to the court with an automaton that he claimed could best human chess masters and complete a complex puzzle called the Knights Tour.

Kempelen’s “Mechanical Turk,” as it came to be known, was a life-size model of a man’s upper half. Dressed in Ottoman robes with a turban and black beard, a smoking pipe in its left hand, the Turk sat at a cabinet with three doors and a chessboard on top. The doors opened to show an intricate set of gears and levers designed to give the audience the illusion of an advanced contraption worthy of the owner’s claims. What remained hidden was a sliding seat behind the gears that enabled a small human chess player to move around as Kempelen showed suspicious spectators the cabinet’s inside, and then to manipulate the contraption once the game began.

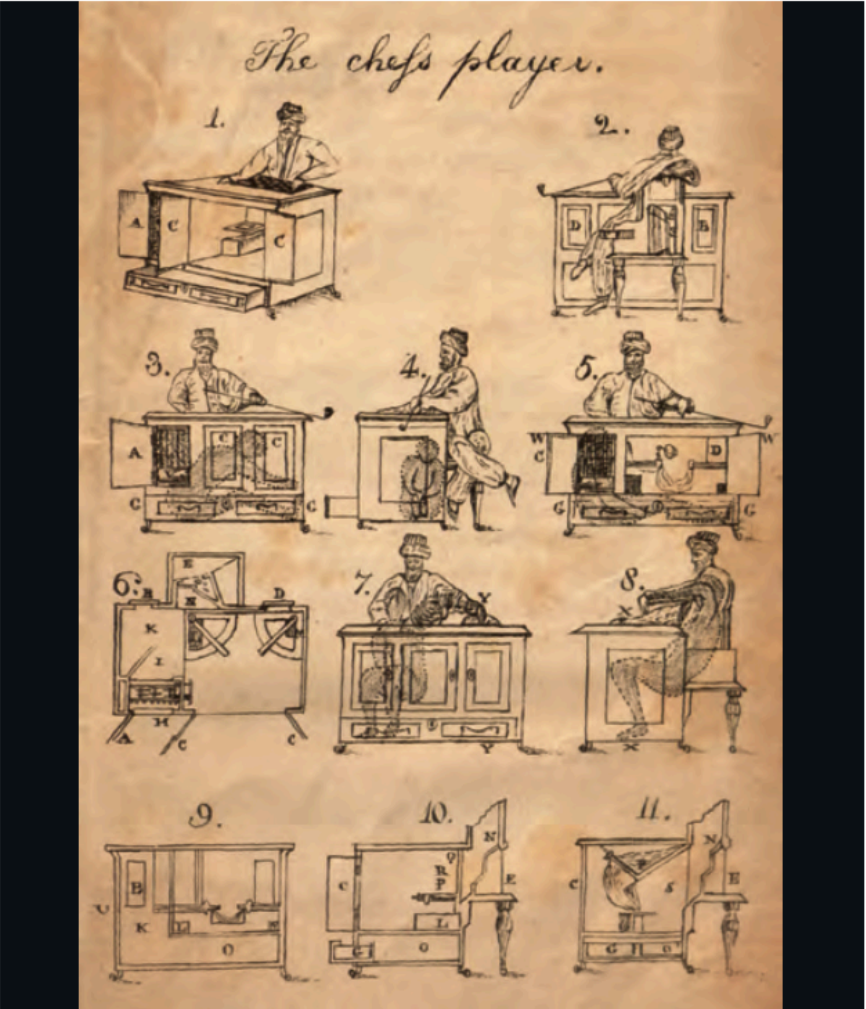
The Turk beat almost everyone it played against, including Benjamin Franklin, who was the US ambassador to France at the time. It also beat the novelist Edgar Allan Poe, as well as Napoléon Bonaparte, whose strategy to beat the Turk was to make a series of deliberately illegal moves. The Turk replaced Napoleon’s piece after the first two moves, and then, after the third, swept its arm across the chessboard, knocking over all of the pieces and ending the game. Napoleon reportedly was amused.

Real or not, the Turk started new dialogue among those who had never considered the potential of mechanized intelligence. Among those was Charles Babbage, whom the Turk beat twice, and who, despite correctly concluding the device was a hoax, drew inspiration from the experience and went on to build the difference engine, the first mechanical computer. The Turk was destroyed in a fire in Philadelphia on July 5, 1854.

SEE ALSO The Difference Engine (1822), Edgar Allan Poe’s “The Gold-Bug” (1843), Computer Is World Chess Champion (1997)

Instead of a machine, a small chess master hid inside the cabinet that held the “Mechanical Turk.” To conceal his presence, the person moved from side to side as the different panel doors were opened.

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1920

Rossum’s Universal Robots

Karel Čapek (1890–1938)

The word *robot* was coined in 1920 by the Czech dramatist Karel Čapek in his science-fiction hit, *R. U. R.* (*Rossum’s Universal Robots*). He coined the word based on the Czech word *robota* (“forced labor”); the word is now widely used for mechanized beings in most languages. In the play, the fictional Rossum corporation has developed cheap, biological humanoid machines called robots and has been shipping them all over the world from its secretive island-based factory. While some nations initially use the robots as soldiers, eventually the world more or less accepts the robots and puts them to work.

R. U. R. included many literary tropes that would become commonplace in future robot literature: an underground organization that seeks to liberate the robots; intelligent robots that are assembled from parts, with short lifespans, no pain, and no emotions; and a likable scientist with questionable ethics. Expensive at first, *R. U. R.*’s robots drop in price from \$10,000 to \$150—from around \$130,000 down to \$2,000 in today’s money. In Čapek’s world, war is a memory, human birthrates are down, and the future seems both predictable and pleasurable. The play’s first act is largely devoted to telling the story of these fantastical creations and posing a philosophical question: if humans need not work, then what purpose do they serve after all?

And then the robots decide to kill every last human on the planet.

Although largely forgotten now, *R. U. R.* was well received and popular. The play was produced in Prague, London, New York, Chicago, and Los Angeles. When Isaac Asimov penned his Three Laws of Robotics, he did so largely to prevent the future that Čapek had envisioned. Although Čapek got the technology wrong—he envisioned that robots would be biological, not based on mechanisms and computation—his compelling vision of a world in which humanity is simultaneously helped, transformed, and eventually smothered by its mechanical creations still haunts us to this day.

SEE ALSO *Metropolis* (1927), Isaac Asimov’s Three Laws of Robotics (1942), *Star Trek* Premieres (1966), Boston Dynamics Founded (1992)

A poster for the Federal Theatre Project presentation of *R. U. R.* at the Marionette Theatre, 1936–1939.

70



1968

HAL 9000 Computer

Stanley Kubrick (1928–1999), Arthur C. Clarke (1917–2008), Douglas Rain (b. 1928)

The HAL 9000 (Heuristically programmed ALgorithmic computer) is a self-aware, artificially intelligent computer that controls the *Discovery* spacecraft in the movie *2001: A Space Odyssey*. HAL accompanies a six-member human crew on an interplanetary mission to Jupiter, four of whom are in suspended animation during the movie and never wake up.

In the movie, astronauts David Bowman and Frank Poole discuss the idea of shutting HAL off when he appears to make a mistake. “No 9000 computer has ever made a mistake or distorted information. We are, by all practical definition of the words, foolproof and incapable of error,” HAL had previously stated in a television interview. So if HAL was making mistakes, the astronauts surmised, then the machine was no longer reliable and had to be shut off.

Of course, as a sentient, self-preserving being programmed to continue the mission if the crew becomes incapacitated, HAL decides that it is the humans who are in error, and decides therefore to kill them.

Visually, HAL is represented in the movie as a red television camera. HAL’s skills include human-like reasoning and conversation, artificial vision, facial recognition, emotional interpretation, opinions on highly subjective topics including art appreciation, and understanding of human interactions. Later, the surviving crew learns that HAL can lip-read.

Directed by Stanley Kubrick and written by science-fiction author Arthur C. Clarke, with technical support by AI pioneer Marvin Minsky, many film critics consider *2001: A Space Odyssey* to be among the best movies ever made. The movie broke new cinematic ground with its cutting-edge special effects and the authenticity of its space exploration narrative. HAL “was the first computer to become a famous personality and become part of public mythology,” said Clarke in a 1992 interview with the *Chicago Tribune*. The movie provoked questions about where technology was heading and the potential consequences of developing an artificial entity that could surpass human intelligence.

SEE ALSO *Rossum’s Universal Robots* (1920), *Star Trek* Premieres (1966)

A movie still from *2001: A Space Odyssey*, showing HAL 9000 depicted as a red television camera.

212



~2050

Artificial General Intelligence (AGI)

The definition and metric that determines whether computers have achieved human intelligence is controversial among the AI community. Gone is the reliance on the Turing test—programs can pass the test today, and they are clearly not intelligent.

So how can we determine the presence of true intelligence? Some measure it against the ability to perform complex intellectual tasks, such as carrying out surgery or writing a best-selling novel. These tasks require an extraordinary command of natural language and, in some cases, manual dexterity. But none of these tasks require that computers be sentient or have sapience—the capacity to experience wisdom. Put another way, would human intelligence be met only if a computer could perform a task such as carrying out a conversation with a distraught individual and communicating warmth, empathy, and loving behavior—and then in turn receive feedback from the individual that stimulates those feelings within the computer as well? Is it necessary to experience emotions, rather than simulate the experience of emotions? There is no correct answer to this, nor is there a fixed definition of what constitutes “intelligence.”

The year chosen for this entry is based upon broad consensus among experts that, by 2050, many complex human tasks that do not require cognition and self-awareness in the traditional biochemical sense will have been achieved by AI. Artificial general intelligence (AGI) comes next. AGI is the term often ascribed to the state in which computers can reason and solve problems like humans do, adapting and reflecting upon decisions and potential decisions in navigating the world—kind of like how humans rely on common sense and intuition. “Narrow AI,” or “weak AI,” which we have today, is understood as computers meeting or exceeding human performance in speed, scale, and optimization in specific tasks, such as high-volume investing, traffic coordination, diagnosing disease, and playing chess, but without the cognition and emotional intelligence.

The year 2050 is based upon the expected realization of certain advances in hardware and software capacity necessary to perform computationally intense tasks as the measure of AGI. Limitations in progress thus far are also a result of limited knowledge about how the human brain functions, where thought comes from, and the role that the physical body and chemical feedback loops play in the output of what the human brain can do.

SEE ALSO The “Mechanical Turk” (1770), The Turing Test (1951)

Artificial general intelligence refers to the ability of computers to reason and solve problems like humans do, in a way that’s similar to how humans rely on common sense and intuition.

512



Even “modern” inventions have deep roots

1703

Binary Arithmetic

Gottfried Wilhelm Leibniz (1646–1716)

All information inside a computer is represented as a series of binary digits—0s and 1s—better known as *bits*. To represent larger numbers—or characters—requires combining multiple binary digits together into binary numbers, also called *binary words*.

We write decimal numbers with the least significant digit on the right-hand side; each successive digit to the left represents 10 times as much as the previous digit, so the number 123 can be explained as:

123 = 1 × 100 + 2 × 10 + 3 × 1

Which is also equal to:

123 = 1 × 10² + 2 × 10¹ + 3 × 10⁰

Binary numbers work the same way, except that the multiplier is 2, rather than 10. So the number one hundred and twenty three would be written:

1111011 = 1 × 2⁶ + 1 × 2⁵ + 1 × 2⁴ + 1 × 2³ + 0 × 2² + 1 × 2¹ + 1 × 2⁰

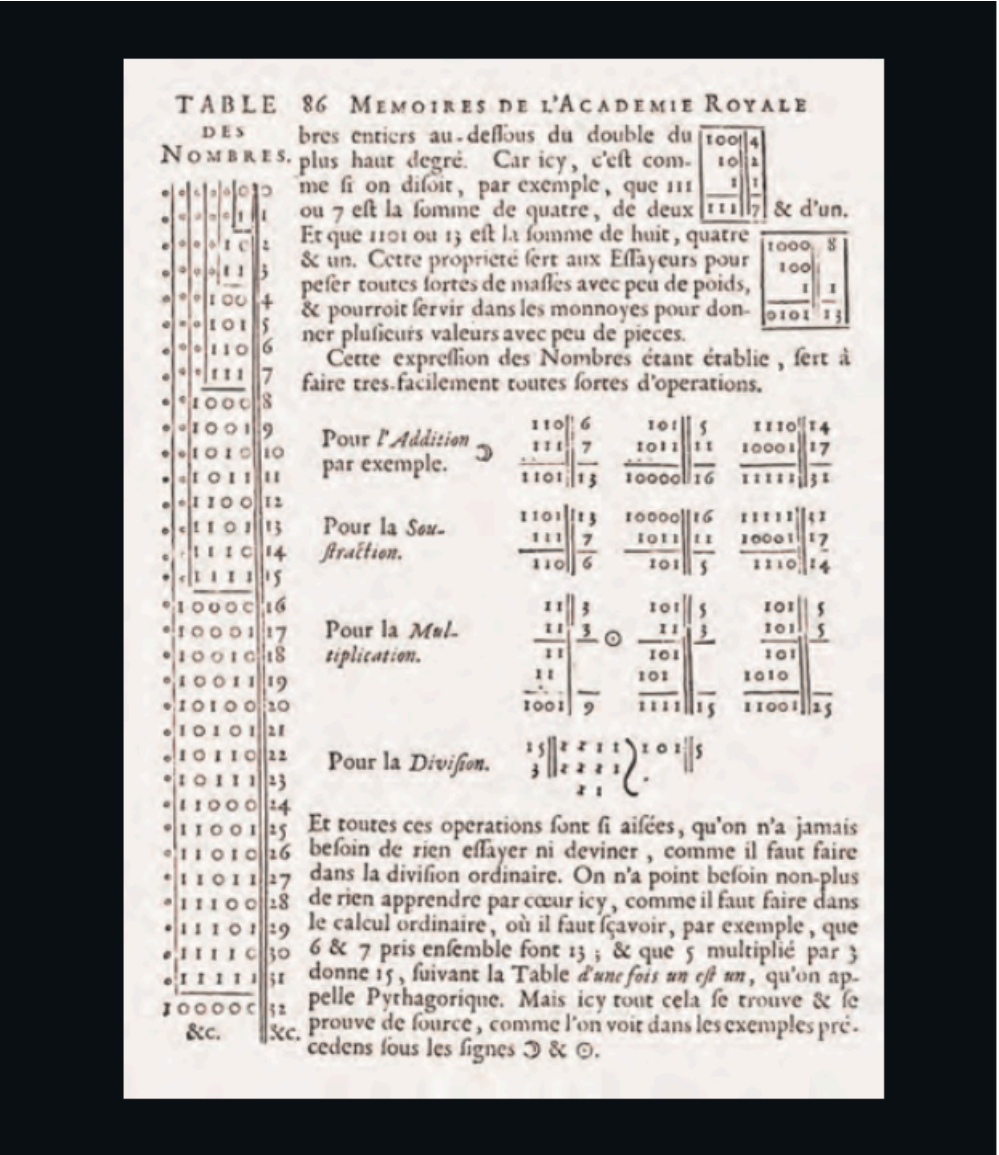
Although forms of binary number systems can be traced back to ancient China, Egypt, and India, it was German mathematician Gottfried Wilhelm Leibniz who worked out the rules for binary addition, subtraction, multiplication, and division and then published them in his essay, “*Explication de l’arithmétique binaire, qui se sert des seuls caractères 0 & 1; avec des remarques sur son utilité, et sur ce qu’elle donne le sens des anciennes figures chinoises de Fohy*” (“Explanation of binary arithmetic, which uses only characters 0 & 1, with remarks about its utility and the meaning it gives to the ancient Chinese figures of Fuxi”).

One of the advantages of binary arithmetic, he wrote, is that there is no need to memorize multiplication tables or to perform trial multiplications to compute divisions: all one needs to do is apply a small set of straightforward rules.

All modern computers use binary notation and perform arithmetic using the same laws that Leibniz first devised.

SEE ALSO Floating-Point Numbers (1914), Binary-Coded Decimal (1944), The Bit (1948)

A table from Gottfried Wilhelm Leibniz’s essay “Explanation of Binary Arithmetic,” published in the *Mémoires de l’Académie Royale des Sciences* in 1703, shows the rules for adding, subtracting, multiplying, and dividing binary numbers.



1864

First Electromagnetic Spam Message

William Fothergill Cooke and Charles Wheatstone’s electromagnetic telegraph took England by storm shortly after commercial service began in 1837. By 1868, there were more than 10,000 miles of telegraph wire in the United Kingdom supporting 1,300 telegraph stations; four years later, there were 5,179 stations, serviced by more than 87,000 miles of wire.

With a capability to reach large numbers of people quickly and easily, the world’s first unsolicited, electrically enabled advertisement was sent in London late in the evening of May 29, 1864, according to historian Matthew Sweet. The message was from Messrs. Gabriel, a group of unregistered dentists, who sold a variety of false teeth, gums, toothpaste, and tooth powder.

The message, sent to current and former members of Parliament, read as follows:

Messrs. Gabriel, dentists, Harley-street, Cavendish-square. Until October Messrs. Gabriel’s professional attendance at 27, Harley-street, will be 10 till 5.

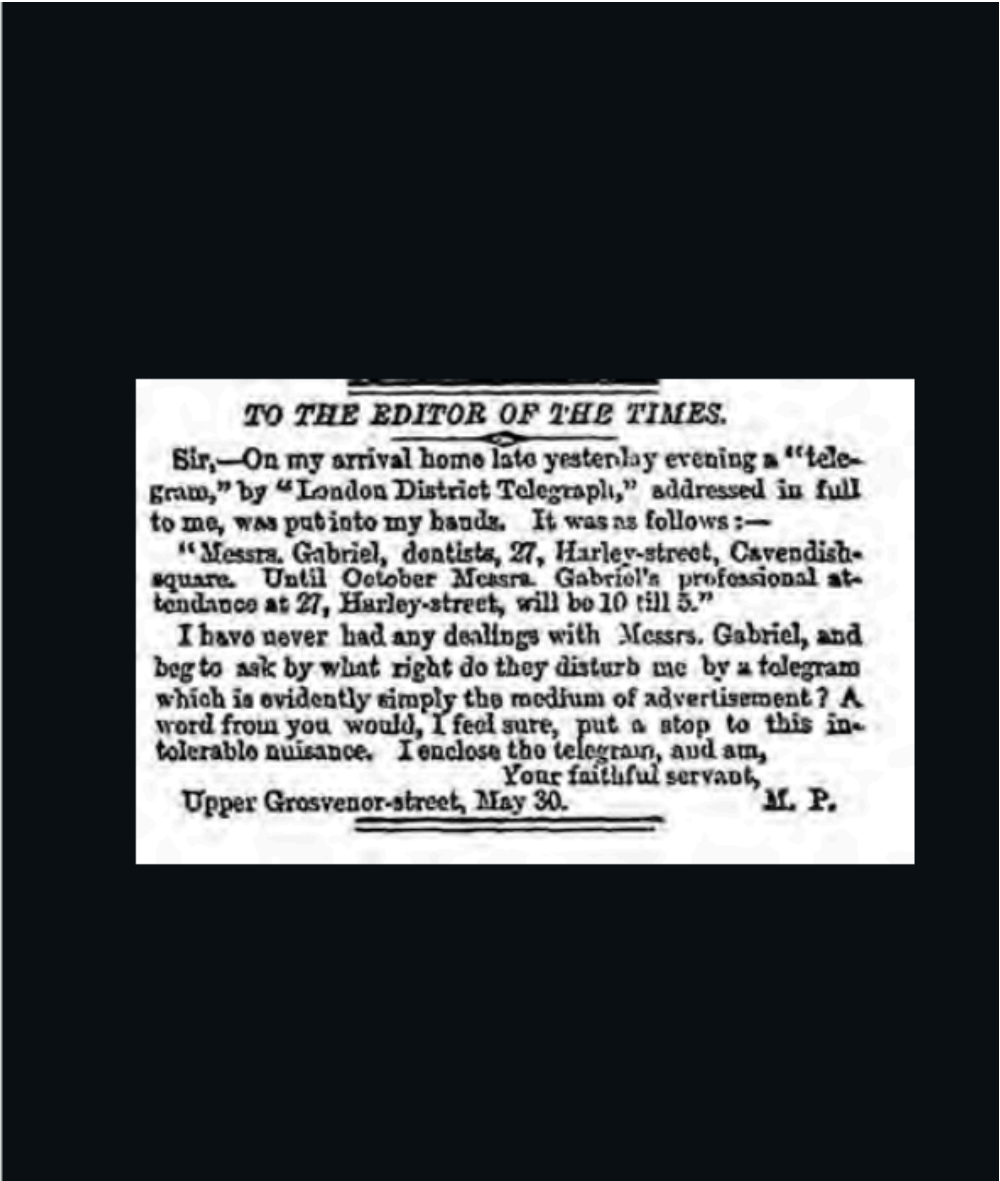
In 1864 there were no telegraphs in private residences; the message appeared on the swinging needles of the Cooke-Wheatstone electromagnetic telegraph, where it was transcribed by operators, carried by a boy sent from the London District Telegraph Company, and placed into the hand of a member of Parliament.

That M.P. wrote about his annoyance in a letter to the editor of the local paper: “I have never had any dealings with Messrs. Gabriel, and beg to know by what right do they disrupt me by a telegram which is simply the medium of advertisement? A word from you would, I feel sure, put a stop to this intolerable nuisance.”

But it wasn’t shame that put a halt to spam sent by telegram: it was the cost. Advertising by telegraph just wasn’t cost effective, due to the high price of sending the messages. That price plummeted with the birth of email, which was used to send a bulk, unsolicited advertisement for the first time in 1978.

SEE ALSO First Internet Spam Message (1978)

On May 29, 1864, Messrs. Gabriel, a group of unregistered dentists, sent members of the British Parliament the earliest known unsolicited electronic message. One recipient complained to the newspaper.



1792

Optical Telegraph

Claude Chappe (1763–1805)

People had used signal fires, torches, and smoke signals since ancient times to send messages rapidly over long distances. The ancient Athenians used flashes of sunlight from their shields to send messages from ship to shore. The Romans coded flags to send messages over a distance—a practice that the British Navy also employed as early as the 14th century.

In 1790, an out-of-work French engineer named Claude Chappe started a project with his brothers to develop a practical system for sending messages quickly over the French countryside. The idea was to set up a series of towers constructed on hills, with each tower in view of the next. Each tower would be equipped with a device that had big, movable arms and a telescope, so that the position of the arms could be determined and then relayed to the next tower. An operator in the first tower would move the arms into different positions, each position signaling a letter, and the operator in the second tower would write it down—essentially sending letters over distance (*tele-graph*) with light. A second telescope would allow for messages to be conveyed in the opposite direction.

After successfully sending a message nearly 9 miles (14 kilometers) on March 2, 1791, Claude and his younger brothers, Pierre François (1765–1834), René (1769–1854), and Abraham (1773–1849), moved to Paris to continue the experiments and drum up support from the new government. Their older brother, Ignace Chappe (1760–1829), was a member of the revolutionary Legislative Assembly, which probably helped somewhat. Soon the brothers were authorized by the Assembly to construct three stations as a test. That test went well, and in 1793 the Assembly decided to replace its system of couriers with optical telegraph lines. Claude Chappe was appointed lieutenant of engineering for the construction of a telegraph line between Paris and Lille, under the control of the Ministry of War.

The first practical demonstration of the telegraph came on August 30, 1794, when the Assembly learned that its army in Condé-sur-l’Escaut had been victorious. That message was transmitted in about half an hour. In the following years, telegraph lines were built across France, connecting all of the major cities. At its height, the system had 534 stations covering more than 3,000 miles (5,000 kilometers). Not surprisingly, Napoléon Bonaparte made heavy use of the technology during his conquest of Europe.

SEE ALSO Machine Patented (1843)

An artist’s impression of Claude Chappe, demonstrating his aerial telegraph semaphore system, from the Paris newspaper *Le Petit Journal*, 1901.



1843

Fax Machine Patented

Alexander Bain (1811–1877), Giovanni Caselli (1815–1891)

Before the telephone, before radio, there was the fax machine. It wasn’t the fax machine of the 1990s—the machine that transmitted information over ordinary phone lines—but rather a machine comprising of a pair of synchronized pendulums connected to each other over distance by an electrified wire.

Alexander Bain was a Scottish clockmaker with an interest in both electricity and invention. In 1843, he built an “electric printing telegraph” that used a pair of precisely timed pendulums, one configured to function like a scanner, the other to function as a remote printer. A message scanned by the first pendulum would print out at the second.

The scanning pendulum had an arm that moved back and forth across a metal plate holding raised metal printers type. After each swing, the plate advanced in the perpendicular direction. Thus, the arm scanned a path of parallel horizontal lines across the type. When a small contact on the arm swept over part of a letter, a circuit would be completed and an electric current would flow down the wire to the remote system, where the synchronized pendulum was scanning horizontal lines over a piece of chemically treated paper. When electricity flowed, the paper under the second pendulum would change color.

Although Bain’s system worked, he ended up in disputes with both Charles Wheatstone (1802–1875) and Samuel Morse (1791–1872). Bain died in poverty in 1877.

Italian inventor Giovanni Caselli improved on Bain’s basic idea with a more compact device called a *pantelegraph*, which transmitted a message written with insulating ink on a metal plate over a set of wires. Commercial operation of the pantelegraph began in 1865 between Paris and Lyon, mostly to verify signatures on banking instructions.

The discovery that the element selenium was also a photoconductor meant that its electrical resistance changed with light, making it possible to send photographic images. This was put to use in 1907 with a “wanted” poster that was sent from Paris to London help catch a jewel thief. Soon newspapers were routinely printing photos that had been sent by wire. In 1920, the Bartlane cable picture transmission system routinely sent digitized newspaper photographs from London to New York, taking three hours to transmit each photograph.

SEE ALSO First Digital Image (1957)

Alexander Bain’s “electric printing telegraph” paved the way for later fax machines, such as this 1960 machine by Alexander Muirhead.



Organized funding by governments launched the information revolution.

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SEE ALSO 📺 Machine Patented (1843)

An artist's impression of Claude Chappe, demonstrating his aerial telegraph semaphore system, from the Paris newspaper Le Petit Journal, 1901.



1822

The Difference Engine

Johann Helfrich von Müller (1746–1830), Charles Babbage (1791–1871)

A difference engine is a machine for tabulating and calculating polynomial functions. It was created to automatically calculate accurate nautical and astronomical tables, because those made by human computers contained too many errors.

The concept originated with Johann Helfrich von Müller in 1786, but it was Charles Babbage, the British mathematician and inventor, who devised an extraordinarily detailed plan of how a functioning engine would work and created working prototypes at a scale that had not previously been conceived. It is perhaps the most intricate blueprint of a machine ever conceived on paper that could function.

Babbage's original difference engine was the first automatic calculator, meaning that it was able to use the results from one calculation as an input to the next. He designed it with 16 decimal digits of accuracy and a printer; it could also produce plates for printing. It was to print not just nautical tables but also tables of logarithms, trigonometric functions, and even artillery tables (the task for which ENIAC, the Electronic Numerical Integrator and Computer, would later be constructed).

With funding from the British government, Babbage hired a machinist to build the engine. But it was never fully realized, and the project shut down in 1842. While manufacturing limitations were a factor in failure, lore has it that a financial dispute with the tool maker was the final, insurmountable obstacle. Babbage did manage to make a small, partial prototype of his second difference engine in 1832. The drawings for the second engine were used to build a fully functional machine that was completed in London in 2002. That machine has 8,000 parts, is 11 feet in length, and weighs 5 tons.

While work on the difference engine was halted, Babbage designed (but never built) the analytical engine, which was to be programmed with punch cards and had a separate "store" where numbers would be kept and a "mill" where the math would be calculated, a design that would be implemented in electronics nearly a century later.

SEE ALSO ⚙️ Antikythera Mechanism (c. 150 BCE), Ada Lovelace Writes a Computer Program (1843), Tabulating the US Census (1890), ENIAC (1943)

The Difference Engine No. 1 by Charles Babbage was the first successful automatic calculator. The portion pictured here was assembled by Babbage's engineer, Joseph Clement, in 1832. Consisting of approximately 2,000 parts, it represents one-seventh of the complete engine.



42

1851

Thomas Arithmometer

Gottfried Wilhelm Leibniz (1646–1716), Charles Xavier Thomas de Colmar (1785–1870)

German philosopher and mathematician Gottfried Leibniz became interested in mechanical calculation after seeing a pedometer while visiting Paris in 1672. He invented a new type of gear that could advance a 10-digit dial exactly 0 to 9 places, depending on the position of a lever, and used it in a machine with multiple dials and levers called the *stepped reckoner*. Designed to perform multiplication with repeated additions and division by repeated subtractions, the reckoner was hard to use because it didn't automatically perform carry operations; that is, adding 1 to 999 did not produce 1,000 in a single operation. Worse, the machine had a design flaw—a bug—that prevented it from working properly. Leibniz built only two of them.

More than 135 years later, Charles Xavier Thomas de Colmar left his position as inspector of supply for the French army and started an insurance company. Frustrated by the need to perform manual arithmetic, Thomas designed a machine to help with math. Thomas's arithmometer used Leibniz's mechanism, now called a *Leibniz wheel*, but combined it with other gears, cogs, and sliding levers to create a machine that could reliably add and subtract numbers up to three digits, and multiply and divide as well. Thomas patented the machine, but his business partners at the insurance firm were not interested in commercializing it.

Twenty years later, Thomas once again turned his attention to the arithmometer. He demonstrated a version at the 1844 French national exhibition and entered competitions again in 1849 and 1851. By 1851, he had simplified the machine's operation and extended its capabilities, giving it six sliders for setting numbers and 10 dials for display results. Aided by three decades' advance in manufacturing technology, Thomas was able to mass-produce his device. By the time of his death, his company had sold more than a thousand of the machines—the first practical calculator that could be used in an office setting—and Thomas was recognized for his genius in creating it. The size of the arithmometer was approximately 7 inches (18 centimeters) wide by 6 inches (15 centimeters) tall.

SEE ALSO 🧮 Curta Calculator (1948)

This Thomas Arithmometer can multiply two 6-digit decimal numbers to produce a 12-digit number. It can also divide.



1890

Tabulating the US Census

Herman Hollerith (1860–1929)

When the US Constitution was ratified, it mandated that the government conduct an "actual enumeration" of every free person in the union every 10 years. As the number of people in the nation grew, the enumeration took longer and longer to complete. The 1880 Census counted 50,189,209 people. It took 31,382 people to perform the count and eight years to tabulate the results, producing 21,458 pages of published reports. So, in 1888, the Census Bureau held a competition to find a better way to process and tabulate the data.

American inventor Herman Hollerith had worked briefly at the Census Bureau prior to the 1880 census and in 1882 joined the faculty of MIT, where he taught mechanical engineering and experimented with mechanical tabulation systems. His early systems used long rolls of paper tape with data represented as punched holes. Then, on a railroad trip to the American West, Hollerith saw how conductors made holes on paper tickets corresponding to a person's hair color, eye color, and so on, so that tickets couldn't be reused by other passengers. Hollerith immediately switched his systems to use paper cards.

Hollerith entered the 1888 competition and won, his system being dramatically faster than those of the two other entrants. On January 8, 1889, he was awarded a US patent on "method, system and apparatus for compiling statistics," originally filed September 23, 1884.

Hollerith's system consisted of a slightly curved card measuring 3.25 by 7.375 inches (83 millimeters by 187 millimeters). A human operator punched holes in the card with a device called a *Pantographic Card Punch*, with holes in specific locations to signify a person's gender, marital status, race, ownership and indebtedness of farms and homes, and other information. For tabulation, the cards were passed through a reader with micro switches to detect the presence of holes and electromechanical circuits to perform the actual tabulation.

SEE ALSO 🧵 The Jacquard Loom (1801), ENIAC (1943)

A woman with a Hollerith Pantographic Card Punch, which creates holes in specific locations to signify a person's gender, marital status, and other information. This photo is from the 1940 US census.



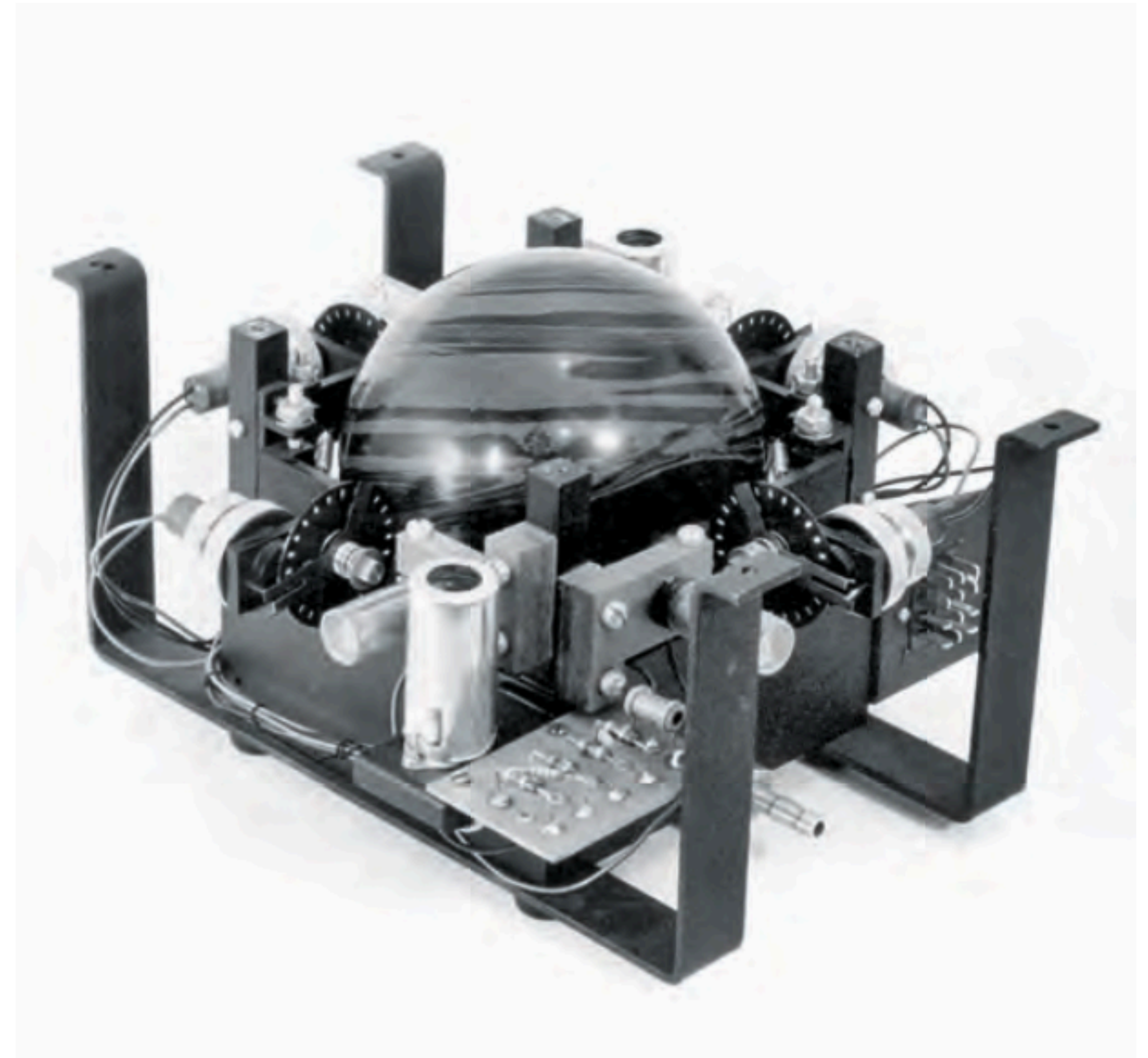
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38

52

Modern computing was created by World War II and its aftermath

- 1941 — Z3 Computer
- 1943 — ENIAC
- 1943 — Colossus
- 1944 — Delay Line Memory
- 1944 — Binary-Coded Decimal
- 1945 — EDVAC First Draft Report
- 1946 — Trackball
- 1946 — Williams Tube
- 1949 — Whirlwind
- 1950 — Error-Correcting Codes



Research results are unpredictable

Whirlwind:

Created to be a flight simulator

Innovations:

First interactive personal computer.

First video game

Light pen

Long-life tubes

Core memory

Never produced a flight simulator

1949

Whirlwind

Jay Forrester (1918–2016), Robert R. Everett (b. 1921)

In 1944, the US Navy asked the MIT Servomechanisms Laboratory to create a flight simulator to train Navy pilots. MIT tried building an analog computer, but it was soon clear that only a digital machine could possibly offer the speed, flexibility, and programmability required to create a realistic simulation. So, in 1945, the Office of Naval Research contracted MIT to create what would be the world's first interactive, real-time computer.

Called *Whirlwind*, the machine was a massive undertaking: the project involved 175 people with a budget of \$1 million a year. The machine used 3,300 vacuum tubes and occupied 3,300 square feet in MIT Building N42, a 25,000-square-foot, two-story building that MIT bought specifically for the project.

Whirlwind had the first computer graphics display, a pair of 5-inch video screens on which the computer could draw airspace maps. It also had the first graphical input device, a "light pen" (invented by associate director Robert R. Everett), for selecting points on the screen. When Whirlwind was partially operational in 1949, MIT professor Charles Adams and programmer John Gilmore Jr. used its graphics capabilities to create one of the first video games: a line with a hole, and a ball that made a *thunk* sound every time it bounced. The goal was to move a hole so that the ball would fall in.

Soon, however, it was clear that the electronics technology of the day needed improving. Whirlwind's vacuum tubes kept burning out. The lab performed an in-depth analysis and determined that trace amounts of silicon in the tube cathodes were at fault. The lab had the contaminant removed, and the lifetime of the tubes was extended by a factor of a thousand. When it became clear that the computer would need memory that was larger and more reliable than storage tubes, Forrester invented magnetic core memory, which would become the primary storage system of computers for the next two decades. Later, when it became evident that Whirlwind needed code that would permanently reside in the computer, load other programs, and provide basic functions, the project drove the invention of the first operating system.

Whirlwind was fully operational in 1951. Although it was never actually used as a flight simulator, its graphic display showed that computers could present maps and track objects, demonstrating the feasibility of using computers for air defense.

SEE ALSO Core Memory (1951)

Created to run a flight simulator for the US Navy, Whirlwind was the world's first interactive computer.



Research results are *really* unpredictable

1927 First LED

Perfected by Vladimirovich Losev to use photoelectric effect for practical applications.

Losev invented radio receiver, solid state amplifier, and other devices. Died of starvation during the Siege of Leningrad in 1942.

Rediscovered in 1962 by four different groups of Americans

1927

First LED

Oleg Vladimirovich Losev (1903–1942)

Although the electroluminescent property of some crystals was discovered in England in 1907, it took more than a decade of work by the self-taught Russian scientist Oleg Vladimirovich Losev to develop a theory (based on Einstein's photoelectric theory) of how the effect worked, and to produce devices that could be used in practical applications. In total, Losev published 16 academic papers that appeared in Russian, British, and German scientific journals between 1924 and 1930, comprehensively describing the devices in the process. He went on to come up with novel applications for light-emitting diodes (LEDs) and other semiconductors, including a "light relay device," a radio receiver, and a solid-state amplifier, before dying of starvation during the Siege of Leningrad in 1942.

LEDs were rediscovered in 1962 by four different groups of American researchers. This time the technology would not be lost. Compared with incandescent, fluorescent, and xenic tubes of the day, LEDs consumed far less power and produced practically no heat. They had just three disadvantages: they could make only red light, they were not very bright, and they were fantastically expensive—more than \$200 each at the beginning.

By 1968, improvements in production let companies push the price of LEDs down to five cents each. At that price, LEDs started showing up in calculators, wristwatches, laboratory equipment, and, of course, computers. Indeed, LEDs arranged as individual lights and seven-segment numeric displays were one of the primary outputs for the first generation of microcomputers in the mid-1970s. Even the early LEDs could be switched on and off millions of times a second, resulting in their use in fiber-optic communications. In 1980, infrared LEDs started showing up in television remotes.

Although blue and ultraviolet LEDs were invented in the 1970s, a number of breakthroughs were required to make them bright enough for practical use. Today those challenges have been overcome. Indeed, the bright-white LED house lights that have largely replaced both incandescent and fluorescent light bulbs are based on an ultraviolet LED that stimulates a white phosphor.

SEE ALSO First Liquid-Crystal Display (1965)

Eight decades after it was invented in 1927, light-emitting diodes were finally bright enough and cheap enough to replace incandescent light bulbs on a massive scale.



1965 First Liquid Crystal

Developed by RCA to replace tubes in color TV

Sold in 1976 to Timex for digital watches

Inventor George Heilmeier left RCA for White House, then DARPA

1965

First Liquid-Crystal Display

George Heilmeier (1936–2014)

The liquid-crystal state of matter was discovered at the Karl-Ferdinands-Universität in Prague in 1888 by Friedrich Reinitzer and further investigated in the 1900s and 1930s. But otherwise, the curious ability of some liquids to have crystalline properties—specifically the ability to change the polarization of light—remained a chemical curiosity, and not the subject of practical exploration or exploitation.

Then, in the early 1960s, engineers at RCA's David Sarnoff Laboratories in Princeton, New Jersey, were looking for a new kind of display that could replace the vacuum tubes used in color TVs. RCA's physical chemist Richard Williams turned his attention to liquid crystals and discovered that certain chemicals, heated to 243° Fahrenheit (117° Celsius), would change their appearance from transparent to opaque when placed in a high-voltage electric field.

Williams soon gave up on the idea of using these crystals for a display, but a young engineer at the company named George Heilmeier saw their promise. Over the following years, Heilmeier and his newly formed research group discovered materials that exhibited the liquid-crystal effect at room temperature and when exposed to very small electric fields.

Heilmeier's group built the first liquid-crystal display in 1965, using a bit of liquid crystal sandwiched between a polarizer and a reflective surface, separately controlling the seven segments of a single-digit display; next, the group created an LCD that displayed a tiny TV test pattern.

In 1971, RCA sold its computing division to Sperry Rand, taking a \$490 million write-off. Doubtful that liquid-crystal displays would ever make money, RCA sold that technology in 1976 to Timex® for its digital watches. Today, LCD screens are used for desktop computers, portable phones, televisions, projectors, and more.

Heilmeier left RCA for a fellowship at the White House, and in 1975 he became director of the Defense Advanced Research Projects Agency (DARPA), where he continued to oversee the development of technology on behalf of the US government.

SEE ALSO First LED (1927), E Ink (1997)

Today, liquid crystal displays (LCDs) are commonly used in television screens.



ALOHANET got on the Internet because of a chance visit to DARPA.

1971

First Wireless Network

Norman Abramson (b. 1932), Robert Metcalfe (b. 1946)

By 1968 it was clear that the voice telephone network would not be adequate to serve the emerging requirements of networked computing. ALOHA was designed to explore the possibility of using wireless communications as a potentially superior alternative to wired.

A team of researchers at the University of Hawaii (UH), led by Norman Abramson, set out with the goal of linking computers on the main campus in Manoa Valley (near Honolulu) with terminals at a college in Hilo, Hawaii—and five community colleges on the islands of Oahu, Kauai, Maui, and Hawaii. If successful, the project would allow students at the schools to use the computers without having to travel to Hilo.

At the time, point-to-point microwave channels were well understood—and expensive. Such channels were also wasteful, because the nature of terminal communication was such that it was sporadic and frequently idle and could tolerate only small delays. Soon the group hit on the idea of sharing a single high-speed wireless channel between all the senders: if a sender didn't get an acknowledgement, it would retransmit its packet until it did.

The first packet was transmitted in June 1971 from a terminal attached by an RS232 interface to a new device called a *terminal control unit* (TCU). With the TCU, the terminal could be used anywhere within 100 miles of the UH campus. Soon the group built more TCUs, networking the islands together with ALOHANET, the world's first wireless computer network.

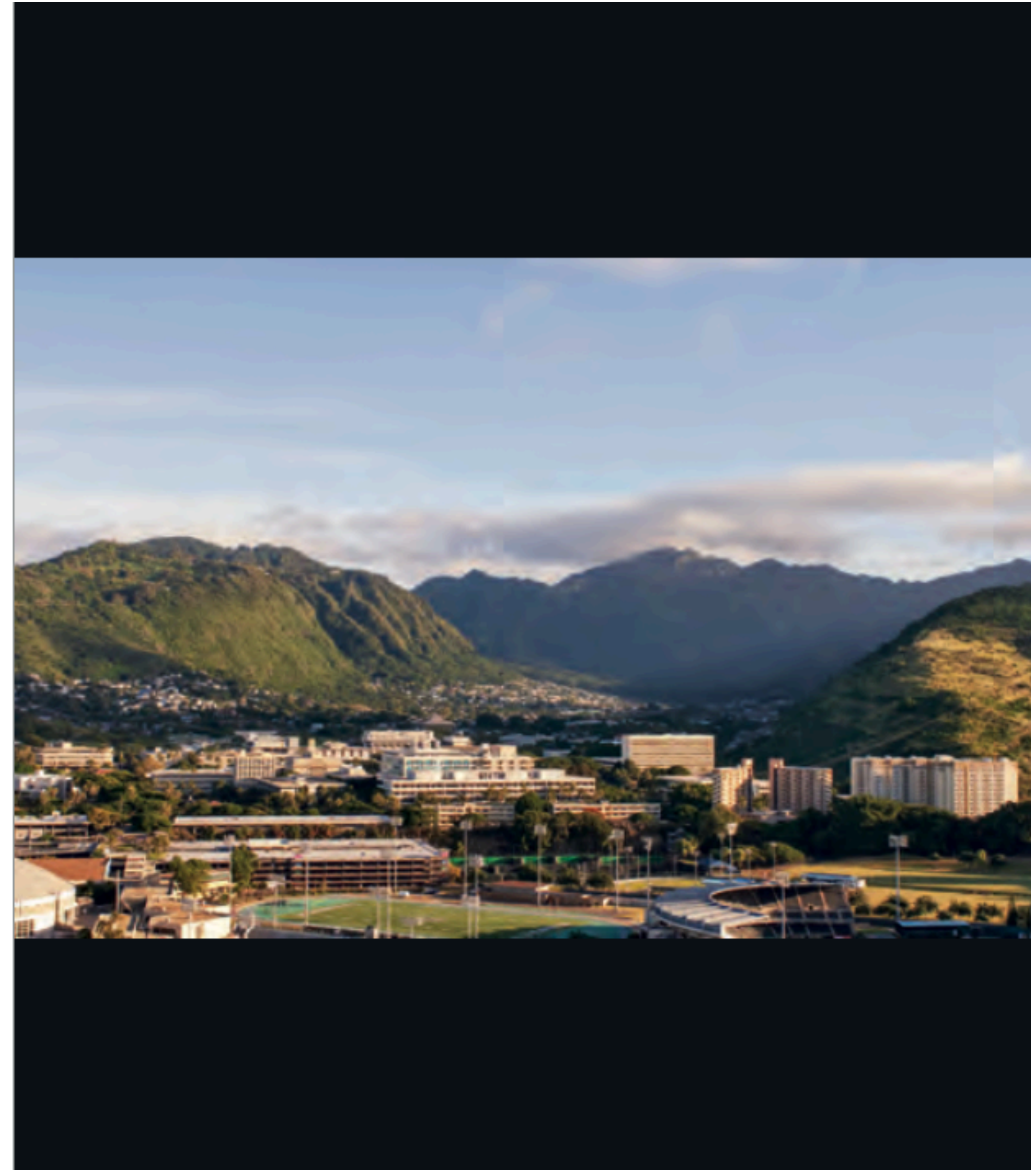
The ALOHANET system was interconnected to the ARPANET on December 17, 1972, over a single 56-kilobits-per-second satellite communications channel.

Electrical engineer Robert Metcalfe realized that the same broadcast architecture could be run over a piece of coaxial cable. He improved the basic protocol by having the radios listen for traffic before sending their packet, an approach called *carrier sense multiple access* (CSMA), and the Ethernet was born.

Versions of the ALOHANET protocol made their way into many other wireless networks, including early cellular systems. But the lasting contribution of the project was the impact on Ethernet protocols and, eventually, today's Wi-Fi standards.

SEE ALSO IPv4 Flag Day (1983)

The campus at the University of Hawaii, Manoa, where computers were linked with terminals at other colleges throughout Hawaii.



Key lessons

The computer is devouring the world.

The industry relies on openness and standardization.

There is a heavy economic and innovation penalty for secrecy.

Invention and innovation are incredibly different.

~~Patents block innovation.~~

We had much fun researching for 350-word articles!

RESTRICTED — Not to be released outside the General Accounting Office except on the basis of specific approval by the Office of Congressional Relations.

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BY THE COMPTROLLER GENERAL

Report To The Chairman

Committee On Government Operations

House Of Representatives

OF THE UNITED STATES

**NORAD's Missile Warning System:
What Went Wrong?**

The importance and criticality of the North American Air Defense Command's (NORAD's) computer system have recently been emphasized when false missile warning messages were generated and the Nation's nuclear retaliatory forces alerted.

The Air Force began a computer upgrade program for NORAD computers in 1968 which is expected to reach initial operational capability in November 1981. Due to poor management causing program delays and the attempt to adapt inadequate computers to the NORAD mission, the system falls short of meeting the requirements of the growing missile warning mission.

NORAD will replace these computers by the late 1980s, but it needs to do more to improve management and warning capability.

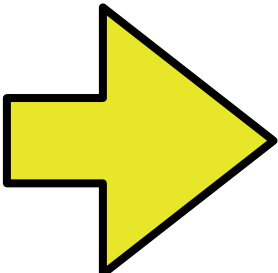
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UNITED STATES
GENERAL ACCOUNTING OFFICE



1983

WarGames

Lawrence Lasker (b. 1949), Walter F. Parkes (b. 1951), John Badham (b. 1939)

WarGames was the movie that transformed the computer nerd into a hero. A blockbuster starring Matthew Broderick and Ally Sheedy, the movie follows high school hacking whiz David Lightman, who almost starts World War III between the United States and the Soviet Union when he breaks into a military supercomputer and challenges it to a game of *Global Thermonuclear War*.

During an online troll for free video games, David unwittingly breaks into a North American Air Defense (NORAD) system that controls the entire US nuclear arsenal (using a back door left by the original programmer, of course). Believing he has found a way to sneak through the back door of a toy company's network, he challenges the computer to play a game that can be "won" only by not playing at all. Only after targeting Las Vegas and Seattle with Soviet missiles does David realize the game is real and the computer he is playing against has taken matters into its own hands as it escalates the crisis in an attempt to "win" the game.

The movie left such an impression on President Ronald Reagan that he asked the chairman of the Joint Chiefs of Staff, General John W. Vessey Jr., if it really was possible to break into sensitive US government computers. After investigating the plausibility of such a scenario, the general came back with his answer: "Mr. President, the problem is much worse than you think." Not long after that, US lawmakers published the *Computers at Risk* report, which established the beginning of the US defensive computer security program.

Written by Lawrence Lasker and Walter Parkes, and directed by John Badham, *WarGames* left an impact on generations of future coders, many of whom went on to work in Silicon Valley—where, in 2008, Google held a 25th-anniversary screening. The movie's legacy has lived on with computer hackers as well—for example, the name of the famous Las Vegas hackers' convention DEFCON is an homage to the film.

SEE ALSO SAGE Computer Operational (1958)

Poster from the movie *WarGames*, written by Lawrence Lasker and Walter Parkes, and directed by John Badham.

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4

Writing Tech and Production

First approach: custom application written in Drupal

Second approach: Google Sheet

Lesson: Demonstrates the power of end-user programmability

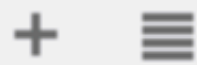


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Year

| | A | B | C | D | E | F | G | H | I | J | K | L |
|----|------|------|---------|-----|--------|------|--------------|------------|-------------|---|-----|---------------|
| 1 | Year | Kill | Asignee | PRB | Turing | NEW! | ate Complete | SENT Batch | Category | Description | Art | Sterling Code |
| 14 | 1770 | | Rachel | | | | 2017-08-12 | | Hardware | Mechanical Turk — Chess playing robot (fraud) | Cl | 11 |
| 15 | 1792 | | Simson | | | | 2017-12-03 | | Networking | Claude Chappe invents the optical telegraph in france | Th | 12 |
| 16 | 1801 | | Rachel | | | | 2017-08-13 | | Hardware | Punchcard controlled weaving — Jacquard loom first der | Ph | 13 |
| 17 | 1822 | | Rachel | | | | 2017-09-30 | | Hardware | Charles Babbage Invents the Difference Engine | Ph | 14 |
| 18 | 1836 | | Simson | | | | 2017-08-19 | | Networking | Samuel F. B. Morse develops the telegraph and the initia | His | 15 |
| 19 | 1840 | | Rachel | | | | 2017-09-14 | | Software | Ada Lovelace writes First Computer Program | pic | 16 |
| 20 | 1842 | X | | | | | | | Theory | First published algorithm | | |
| 21 | 1842 | X | Simson | | | | | | Hardware | Mechanical Calculator (Pascal) | Pa | 268 |
| 22 | 1843 | | Simson | | | | 2017-08-17 | | Networking | Fax Machine Patented | Art | 17 |
| 23 | 1843 | | Rachel | | | | 2017-08-17 | | Culture | Edgar Allan Poe publishes The Gold-Bug a story that fe | Ph | 18 |
| 24 | 1851 | | Simson | | | | 2017-12-02 | | Hardware | Arithmometer | | 269 |
| 25 | 1854 | | Simson | | | | 2017-10-29 | | Theory | Boolean algebra invented (by Boole) | Co | 19 |
| 26 | 1864 | | Simson | | | | 2017-07-18 | | Networking | First electric spam message | pri | 20 |
| 27 | 1872 | X | Simson | | | | | | | Sir William Thomson's Tide-predicting machine | | 270 |
| 28 | 1874 | | Simson | | | NEW | 2017-07-29 | | Information | Baudot code | | 21 |
| 29 | 1874 | | Simson | | | | 2017-12-06 | | Hardware | Semiconductor diode discovered by Ferdinand Braun in | his | 22 |
| 30 | 1890 | | Simson | CEN | | | 2017-07-20 | | Storage | Hollerith Punched Cards Tabulate the 1890 Census | his | 23 |
| 31 | 1891 | | Simson | | | | 2017-12-06 | | Networking | Strowger Step-by-Step Switch | | 260 |
| 32 | 1896 | X | | | | | | | Hardware | Hollerith founds The Tabulating Machine Company, which eventually becom | | |



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| | Year | | | | | | | | | | | | |
|----|------|------|---------|-----|--------|------|-------------|------------|-------------------------|--|--|---------------|--|
| | A | B | C | D | E | F | G | H | I | J | K | L | |
| 1 | Year | Kill | Asignee | PRB | Turing | NEW! | ate Complet | SENT Batch | Category | Description | Art | Sterling Code | |
| 59 | 1947 | | Simson | PRB | | | 2017-08-30 | | Hardware | First case of actual bug being found | Fa | 42 | |
| 60 | 1947 | X | | | | | | | Software | Simplex Algorithm (Linear Programming) | | | |
| 61 | 1947 | | Simson | | | | 2017-10-29 | | Hardware | First Silicon Transistor | | 259 | |
| 62 | 1948 | | Simson | | | | 2017-12-10 | | Hardware | Manchester Small-Scale Experimental Machine (SSEM) ("Baby") | | 272 | |
| 63 | 1948 | X | | | | | | | Culture | Cybernetics published by Norbert Wiener | | | |
| 64 | 1948 | | Simson | | | | 2017-12-02 | | Hardware | Curta mechanical calculator | Cu | 273 | |
| 65 | 1948 | | Simson | PRB | | | 2017-07-23 | | Information | Shannon's Mathematical Theory of Communications (co-authored with Vannevar Bush) | Ph | 43 | |
| 66 | 1949 | X | | | | | | | Hardware | Manchester Mark I | | | |
| 67 | 1949 | | Simson | | | | 2017-11-13 | | Hardware | Whirlwind I computer | | 264 | |
| 68 | 1949 | X | | | | | | | Hardware | Integrated Circuit (Siemens AG) | Co | 44 | |
| 69 | 1950 | | Simson | | | | 2017-12-13 | | Theory | Error Correcting Codes | Pe | 45 | |
| 70 | 1950 | X | | | | | | | Hardware | Drum Memory on Atlas Computer | | | |
| 71 | 1951 | | Simson | | | | 2017-12-02 | | | Microprogramming | | 274 | |
| 72 | 1951 | X | | | | | | | Hardware | Squee: The Robot Squirrel | | | |
| 73 | 1951 | | Simson | | | | 2017-05-20 | 1 | Theory | The Turing Test | Ma | 46 | |
| 74 | 1951 | | Simson | | | | 2017-08-12 | | Storage | Magnetic Tape Storage | Big | 47 | |
| 75 | 1951 | | Simson | | | | 2017-08-12 | | Hardware | Core Memory | Ph | 49 | |
| 76 | 1952 | | Rachel | | | | 2017-11-10 | | Artificial Intelligence | Computer Speech Recognition — Single-speaker digit recognition | http://www.cse.cmu.edu/~prg/ | 48 | |
| 77 | 1952 | X | | | | | | | Software | Huffman Data Compression | | | |



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fx Real time stats:

| | A | B | C | D | E | F | G | H | I | J | K |
|----|--|-----------|--------------|-----------------|-------------------|----------------------|-----------------|-----------------|----------------|------------------------|----------------|
| 1 | Real time stats: | | | | | | | | | | |
| 2 | Total in Complete Status: | | 245 | | | Milestones Required: | | 5.00 | | | |
| 3 | Start Date: | | 15-May-2017 | | | Days Remaining: | | 3 | | | |
| 4 | Today: | | 12-Dec-2017 | | | | | | | | |
| 5 | Elapsed days: | | 211 | | | | | | | | |
| 6 | Cumulative rate: | | 1.16 | milestones/day | | | | | | | |
| 7 | Milestones written in last 7 days: | | 18 | milestones | | | | | | | |
| 8 | Rate over last 7 days: | | 2.57 | milestones/day | | | | | | | |
| 9 | Final Project Due: | | 15-Dec-2017 | | 3 days from today | | | | | | |
| 10 | ETA at Cumulative rate: | | 16-Dec-2017 | | 1 days late | | | | | | |
| 11 | ETA at rate of 7 days: | | 27-Dec-2017 | | 12 days late | | | | | | |
| 12 | | | | | | | | | | | |
| 13 | Work to date (tracker) (Date & Completed manually entered) | | | | | Badness Meter | | | | | |
| 14 | Date | Completed | Elapsed Days | Rate (arts/day) | ETA | Deadline | Days from Start | Days from Today | Milestones Due | Milestones Needed | Milestone Need |
| 15 | 2017-05-27 | 3 | 12 | 0.25 | February 9, 2020 | Jul-15 | 61 | n/a | 50 | COMPLETED ON TIME | |
| 16 | 2017-06-02 | 12 | 18 | 0.67 | May 25, 2018 | Sep-14 | 122 | n/a | 150 | Completed 24 days late | |
| 17 | 2017-06-18 | 36 | 34 | 1.06 | January 6, 2018 | Dec-15 | 214 | 3 | 250 | COMPLETED 2 DAYS EARLY | |
| 18 | 2017-06-30 | 48 | 46 | 1.04 | January 9, 2018 | | | | | | |
| 19 | 2017-07-17 | 55 | 63 | 0.87 | February 25, 2018 | | | | | | |
| 20 | 2017-07-25 | 65 | 71 | 0.92 | February 12, 2018 | | | | | | |
| 21 | 2017-08-02 | 70 | 70 | 0.92 | February 12, 2018 | | | | | | |





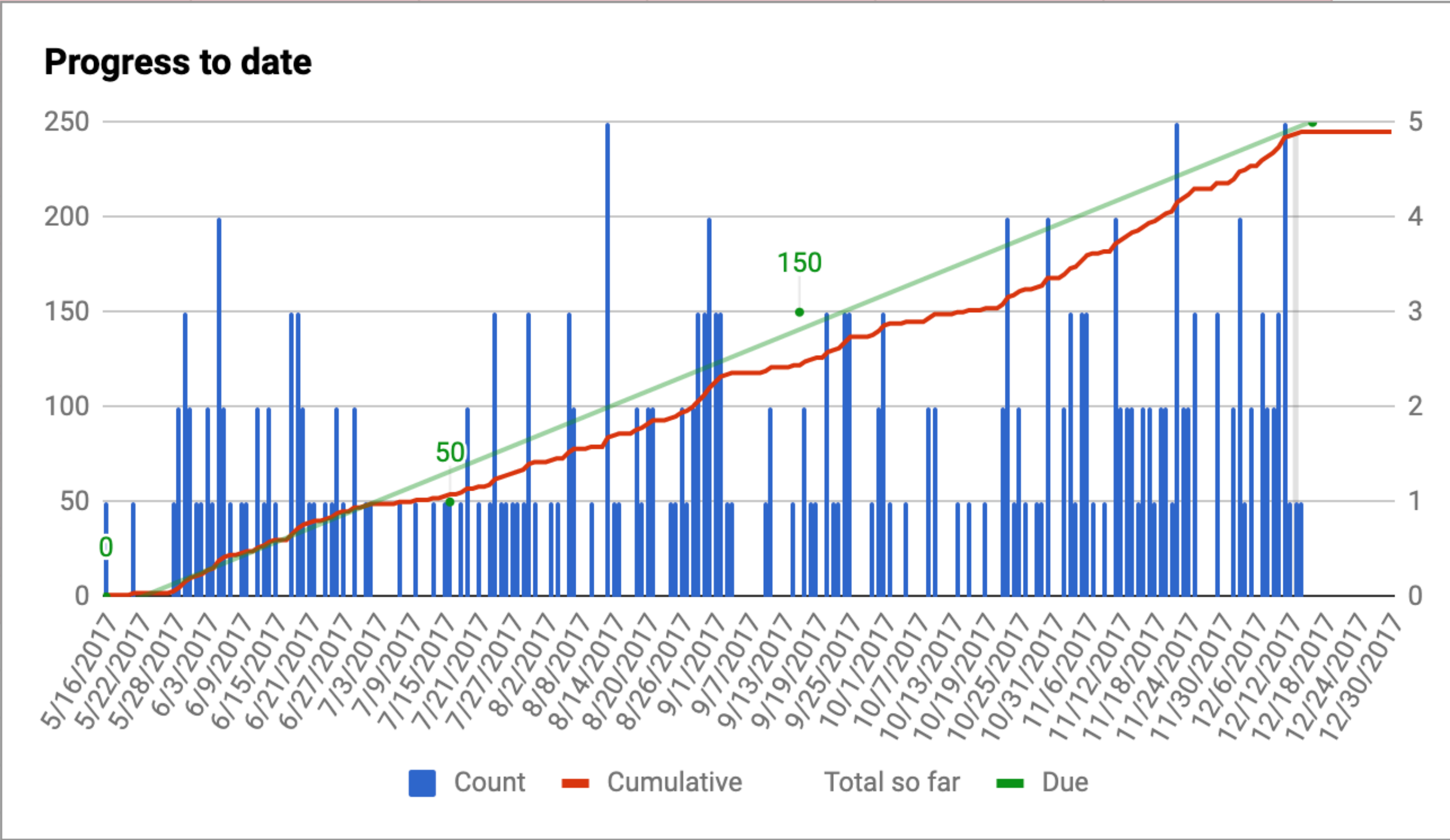
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fx Real time stats:

| | B | C | D | E |
|----|-----|-----|------|-------------------|
| 18 | 48 | 46 | 1.04 | January 9, 2018 |
| 19 | 55 | 63 | 0.87 | February 25, 2018 |
| 20 | 65 | 71 | 0.92 | February 12, 2018 |
| 21 | 73 | 79 | 0.92 | February 9, 2018 |
| 22 | 86 | 89 | 0.97 | January 28, 2018 |
| 23 | 95 | 96 | 0.99 | January 22, 2018 |
| 24 | 120 | 110 | 1.09 | December 30, 2017 |
| 25 | 124 | 118 | 1.05 | January 7, 2018 |
| 26 | 128 | 126 | 1.02 | January 16, 2018 |
| 27 | 150 | 146 | 1.03 | January 13, 2018 |
| 28 | 158 | 160 | 0.99 | January 23, 2018 |
| 29 | 169 | 167 | 1.01 | January 17, 2018 |
| 30 | 183 | 174 | 1.05 | January 7, 2018 |
| 31 | 195 | 182 | 1.07 | January 3, 2018 |
| 32 | 202 | 186 | 1.09 | December 31, 2017 |
| 33 | 229 | 201 | 1.14 | December 20, 2017 |
| 34 | 235 | 205 | 1.15 | December 19, 2017 |
| 35 | 242 | 208 | 1.16 | December 15, 2017 |
| 36 | 250 | 212 | 1.18 | December 13, 2017 |
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fx =query(DB,"Select L, A, J, K where (B != 'X') order by L ",1)

| | A | B | C | D |
|----|----------------------|-------------|---|--|
| 1 | Sterling Code | Year | Description | Art Suggestion |
| 2 | 1 | -2500 | Sumerian abacus | Photo of a sumerian abacus |
| 3 | 2 | -700 | Scytale | Photo of a scytale or a reproduction |
| 4 | 3 | -150 | Antikythera mechanism | Split photo of the original and one of the reconstructions. See https://www.bibliotecapleyades.net/ciencia/esp_ciencia_antikythera02.htm and https://www.youtube.com/watch?v=IT0gXa1ZrnA . One reconstruction is physical, the other v |
| 5 | 4 | 850 | On Deciphering Cryptographic Messages | Photo of the book? Syria put out a stamp with Al-Kindi on it, which can be seen at http://www.muslimheritage.com/article/al-kindi-cryptography-code-breaking-and-ciphers |
| 6 | 5 | 1470 | Leon Battista Alberti develops the cipher disk | There are many beautiful cipher disks, many from the civil war |
| 7 | 6 | 1613 | Term Computer Coined (human computation) | The book "when computers were human" has many photos of women in rooms doing calcula also https://publicdomainreview.org/2016/11/10/let-us-calculate-leibniz-llull-and-computational-ima |
| 8 | 7 | 1621 | Slide rule invented | Historic photo of slide rule |
| 9 | 8 | 1703 | Binary Arithmetic | Diagram of the iChing with their binary equivalent;P. 85, showing Leibnitz's table, from Des (the second page of Leibnitz's article), available at https://hal.archives-ouvertes.fr/ads-00104781/document ; See also: https://publicdomainreview.org/2016/11/10/let-us-calculate-leibniz-llull-and-computational-ima |
| 10 | 9 | 1758 | Halley's Comet Predicted by Human Computers | Painting of Haley with comet in background, if it exists. If not, perhaps one of these. https://www.pinterest.com/pin/493707177878991473/ |
| 11 | 11 | 1770 | Mechanical Turk — Chess playing robot (fraud) | Classic drawing of the Turk. There are many |
| 12 | 12 | 1792 | Claude Chappe invents the optical telegraph in france | The wikipedia page has several historic works. https://en.wikipedia.org/wiki/Claude_Chappe |
| 13 | 13 | 1801 | Punchcard controlled weaving — Jacquard loom first demonstrated | Photo of a Jacquard loom, showing the punch cards |
| 14 | 14 | 1822 | Charles Babbage Invents the Difference Engine | Photo of the engine, or one of the modern reconstructions |



Whoops

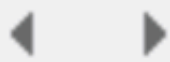
Tracking

Simson TTD

Rachel TTD

TOC For Publisher

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Explore





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fx

Completed Milestones

| | A | B | C | D | E | F | |
|----|----------------------|---|---|---|---|---|--|
| 1 | Completed Milestones | | | | | | |
| 2 | Year | Description | | | | | |
| 3 | -2500 | Sumerian abacus | | | | | |
| 4 | -700 | Scytale | | | | | |
| 5 | -150 | Antikythera mechanism | | | | | |
| 6 | 60 | Programmable Robot | | | | | |
| 7 | 850 | On Deciphering Cryptographic Messages | | | | | |
| 8 | 1470 | Leon Battista Alberti develops the cipher disk | | | | | |
| 9 | 1613 | Term Computer Coined (human computation) | | | | | |
| 10 | 1621 | Slide rule invented | | | | | |
| 11 | 1703 | Binary Arithmetic | | | | | |
| 12 | 1758 | Halley's Comet Predicted by Human Computers | | | | | |
| 13 | 1770 | Mechanical Turk — Chess playing robot (fraud) | | | | | |
| 14 | 1792 | Claude Chappe invents the optical telegraph in france | | | | | |
| 15 | 1801 | Punchcard controlled weaving — Jacquard loom first demonstrated | | | | | |
| 16 | 1822 | Charles Babbage Invents the Difference Engine | | | | | |
| 17 | 1836 | Samuel F. B. Morse develops the telegraph and the initial version of the morse code | | | | | |
| 18 | 1840 | Ada Lovelace writes First Computer Program | | | | | |
| 19 | 1843 | Fax Machine Patented | | | | | |
| 20 | 1843 | Edgar Allan Poe publishes The Gold-Bug a story that features cryptography | | | | | |
| 21 | 1851 | Arithmometer | | | | | |
| 22 | 1854 | Reckon clock invented (by Babbage) | | | | | |



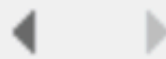
Rachel TTD ▾

TOC For Publisher ▾

Completed ▾

In Progress ▾

Dropped ▾

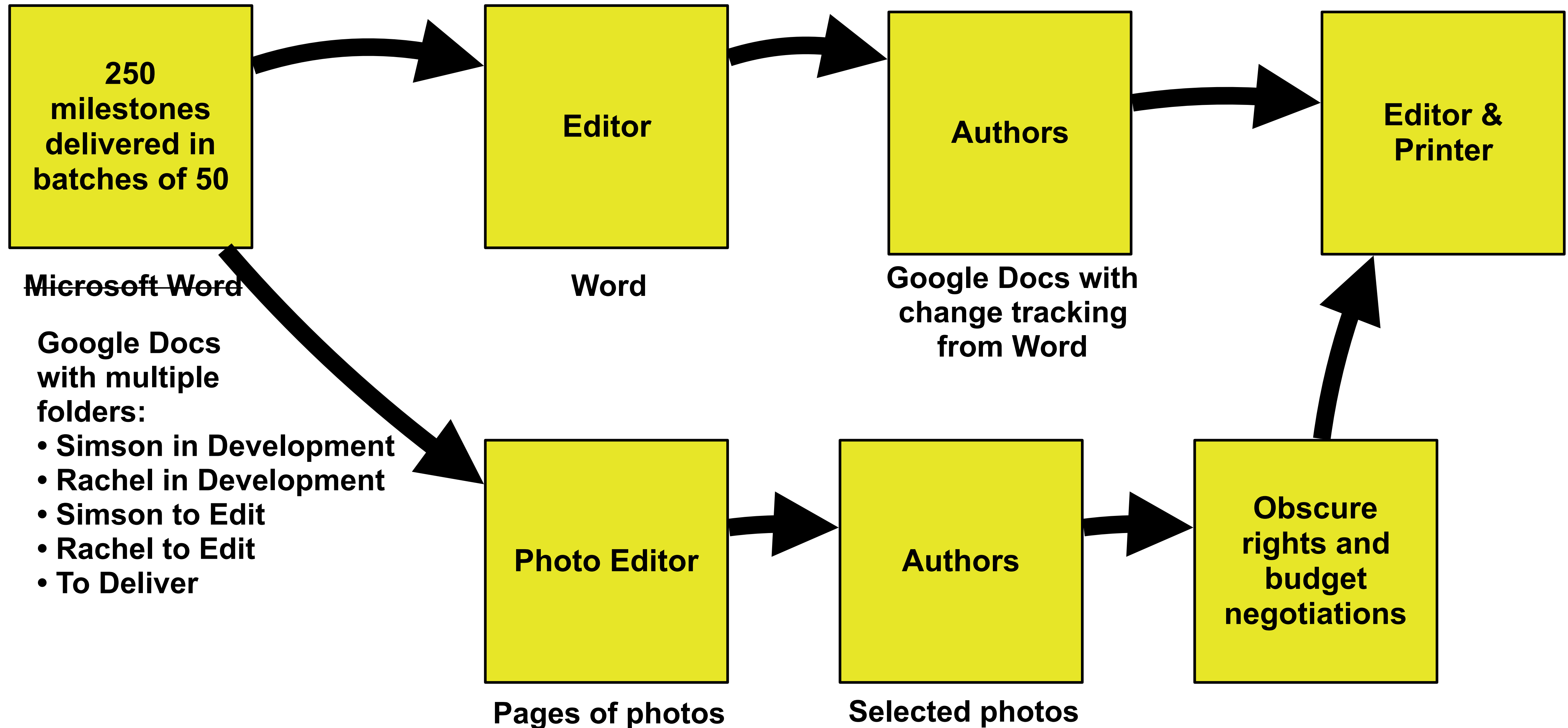




31



Editorial Flow





Copyright issues...

[AU: I'm wary of exactly reproducing the three laws from Asimov's text, which is not PD. Can you instead summarize/paraphrase the three laws?]

1. We believe it would be a mistake not to print.
2. We performed the 4-part copyright test for "fair use."
3. We contacted the copyright owner and got a quote.

permissions.penguinrandomhouse.com/my_requests.php?

Census ▾NPRGMU ▾VA ▾apps ▾\$ ▾news ▾doc ▾ref ▾GmailShop ▾FacebookTTD ▾Jobs ▾Stats ▾Learn ▾AWS ▾CNNOverview - S...ocumentation

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Permissions

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|------------|---------------------|-----------------------------------|-----------|-----------------------|-------------|------------|
| 0000033116 | Print/digital/audio | The Computer Book | Completed | I, Robot | Feb 05 2018 | |

Previous

1

Next

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54

February 12, 2018

From: Dercole, Alicia adercole@penguinrandomhouse.com 
Subject: Permissions request ID 33116 I, ROBOT by Asimov
Date: February 12, 2018 at 9:33 PM
To: simsong@acm.org

AD

Hi Simson

Thanks for submitting this request online. Can you please send me a copy of the material you would like to use as you plan to use it?

Thanks!



Alicia M. Dercole
Senior Associate, Permissions
Penguin Random House
1745 Broadway, 15th Floor
New York, NY 10019
P: 212-940-7681, F: 212-572-6066 E: adercole@penguinrandomhouse.com

Please visit our [website](#) to submit a permissions request.

February 12, 2018

From: Simson Garfinkel simsong@acm.org
Subject: Re: Permissions request ID 33116 I, ROBOT by Asimov
Date: February 12, 2018 at 10:09 PM
To: Dercole, Alicia adercole@penguinrandomhouse.com
Cc: rachel_and_simson@nitroba.com



Hi Alicia,

Thank you so much for your email!

The amount that we wish to use is precisely the three laws, nothing more, nothing less. That is, we wish permission to reprint this 60 word excerpt:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

We also wish to reprint the “zeroth” law:

0. A robot may not harm humanity, or, by inaction, allow humanity to come to harm.

We wish to reprint the three laws on a page of our book that celebrates Asimov’s contribution to computing. Here is the proposed page:

=====

March 11, 2018

From: Simson Garfinkel simsong@acm.org
Subject: Re: Permissions request ID 33116 I, ROBOT by Asimov
Date: March 11, 2018 at 8:16 PM
To: Dercole, Alicia adercole@penguinrandomhouse.com
Cc: rachel_and_simson@nitroba.com



Hi Alicia,


I am asking you again about the status of request ID 33116. We are going into the layout phase of production and need to know if Penguin Randomhouse will be able to give us permission to reprint Issac Asimov's Laws of Robotics, which appears below:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

Thank you very much! I look forward to hearing from you.

Simson Garfinkel

March 19, 2018

From: adercole@penguinrandomhouse.com 
Subject: Request ID: 33116 / Contract ID: 21859
Date: March 19, 2018 at 9:53 AM
To: simsong@acm.org



YOUR PROJECT: The Computer Book

Dear Requester,

A Permission contract for your above-referenced request is attached. Please print two copies and return one counter-signed copy and payment according to the terms of the contract, keeping one copy for your files.

If you have any questions regarding this contract, please contact the sender of this email and be sure to reference the Request ID and/or Contract ID.

If any requested selections or rights are not covered by the attached contract and are not addressed above, you can expect to receive additional correspondence from our department soon.

Thank you.

Sincerely,
Penguin Random House LLC Permissions Department

Terms

Non-refundable fee due within 45 days.

Territory Granted: World

Credit Line: "Three Laws of Robotics" from I, ROBOT by Isaac Asimov, copyright © 1950 and renewed 1977 by Isaac Asimov. Used by permission of Bantam Books, an imprint of Random House, a division of Penguin Random House LLC. All rights reserved." (40 words)

Three laws: 61 words

Total quantity for all formats/editions not to exceed: 30,000 copies

Term of License: 5 years from Publication date

1942

Isaac Asimov's Three Laws of Robotics

Isaac Asimov (1920–1992)

Science-fiction author Isaac Asimov introduced the Three Laws of Robotics in his 1942 story “Runaround” as a set of guiding principles to govern the behavior of robots and their future development. First, a robot may not cause harm to a human, either by the robot’s action or inaction. Second, the robots must follow human commands, unless they would violate the first law. The third law states that robots must look to their own survival, provided that doing so does not interfere with their obligations under the first and second laws.

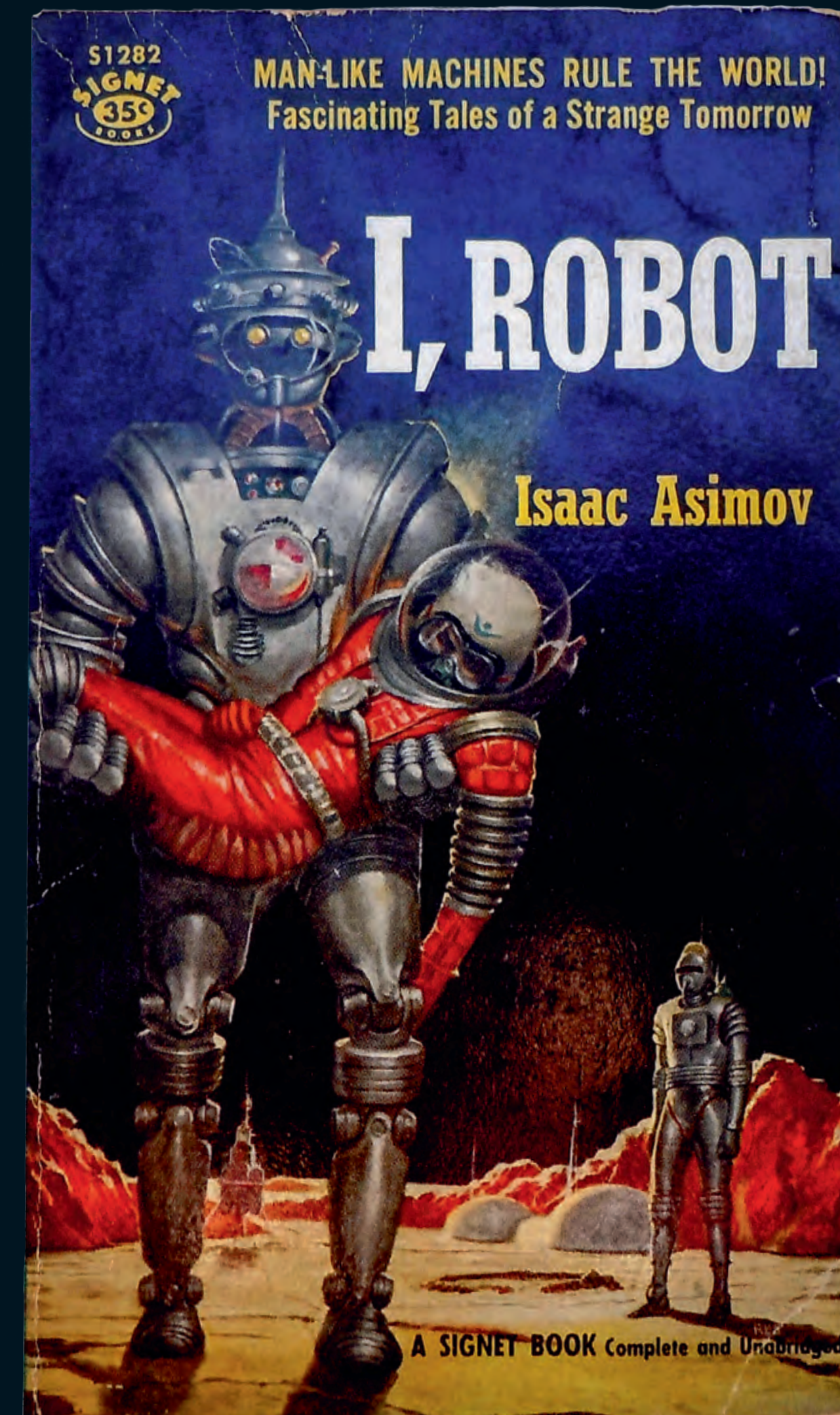
Asimov added a fourth law, known as the “zeroth” law, in 1985. It ranks higher than the first three and affords similar protections to all of humanity.

Asimov originally attributes the laws to the *Handbook of Robotics, 56th Edition, 2058 A.D.* The laws are a fail-safe feature used to inform robot behavior as robots interact with humans and choose courses of action that involve morality, ethics, and thoughtful decision making. They are used throughout the Robot series and other narratives linked to it. For example, Dr. Susan Calvin, a robopsychologist, is a recurring fictional character in Asimov’s robot stories. Calvin is employed by 21st-century robot manufacturer US Robots and Mechanical Men, Inc., where she solves problems caused by robots’ interaction with humans. These problems are often associated with a term in Asimov’s stories called the “Frankenstein Complex,” understood as human fear of self-aware, autonomous machines.

Asimov recognized in his writing that anxiety about intelligent robots would be a significant challenge to overcome in order for robots to be accepted by human society. His laws tapped into a subject that has moved from fiction to public policy as society confronts the commercialization of machines (such as autonomous vehicles) whose function is directly associated with human life.

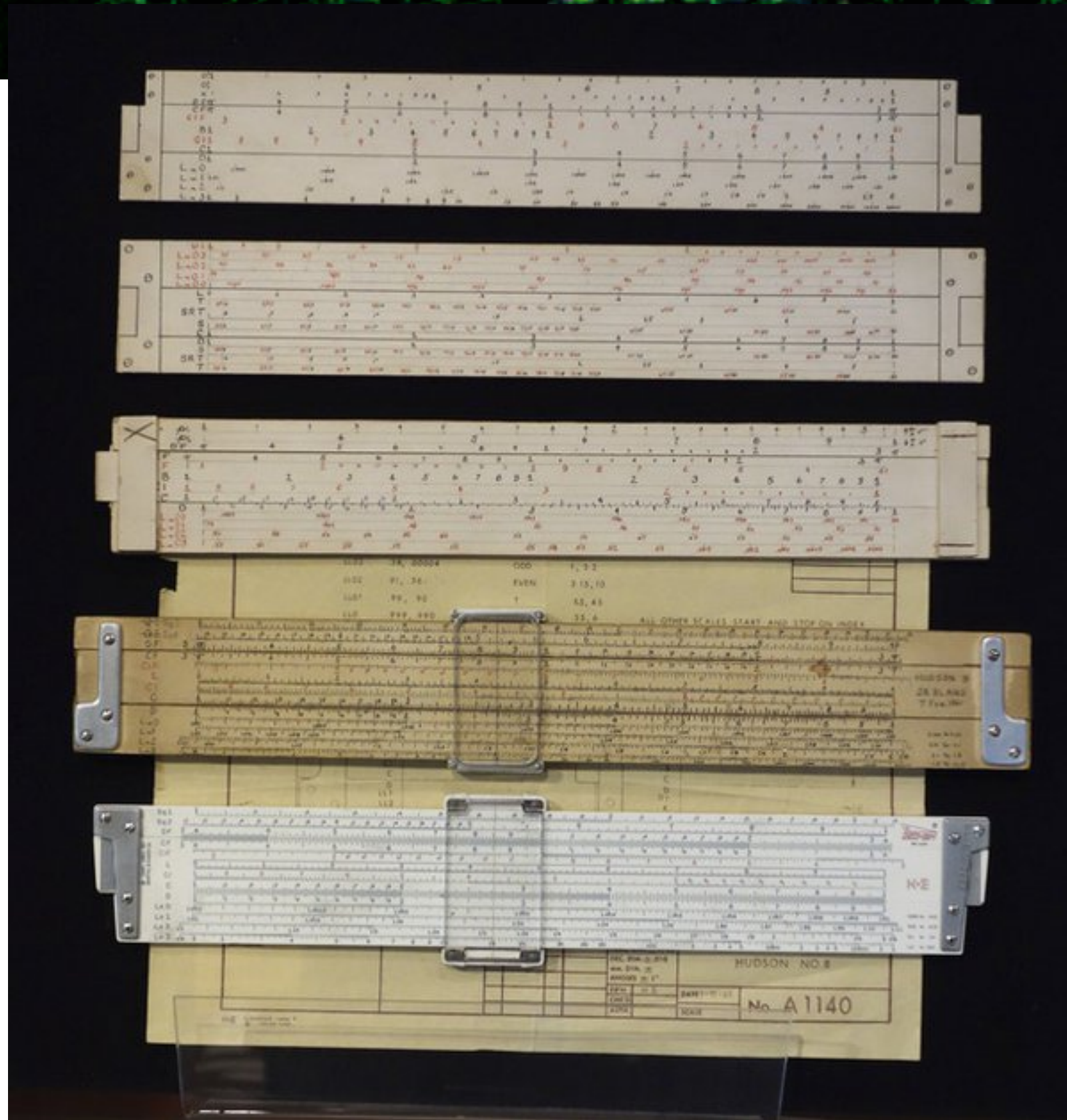
SEE ALSO *Rossum’s Universal Robots* (1920)

Cover of Signet’s 1956 edition of *I, Robot* by Isaac Asimov.





Choosing the art



What they didn't tell us about the art

Wikipedia is the most desirable

iStockPhoto is second best

Shutter Stock is pretty good

Getty Photos and Alamay are the least desirable

Art!



Pixar

Ed Catmull (b. 1945), **Alvy Ray Smith** (b. 1943), **Steve Jobs** (1955–2011)

Pixar may be best known for creating movies such as *Toy Story*, *Cars*, and *Inside Out*, among others, but it is also famous for the pioneering computer animation techniques and technologies it designed to bring its creative visions to life.

Now a subsidiary of the Walt Disney Company®, Pixar originated at the New York Institute of Technology's Computer Graphics Lab, where George Lucas found and hired away Ed Catmull and Alvy Ray Smith to run the computer division at Lucasfilm. Lucas sold the computer division to Steve Jobs in 1986, and it became an independent company called *Pixar*. Disney purchased Pixar on January 25, 2006, at a valuation of \$7.4 billion.

Pixar's proprietary animation rendering technology—RenderMan®—is an industry standard that has received both scientific and technical awards for advances in realistic visual effects, including lighting, shading, and shadowing. The program also embodies techniques for processing the large amounts of 3-D data required for an animated movie. RenderMan's first trip to the red carpet was in 1989, when Pixar's short film *Tin Toy* became the first computer-animated film to receive an Oscar® when it was named Best Short Film (Animated). Since then, RenderMan has been used in numerous Academy Award®-winning films and was acknowledged with its own Oscar in 2001, when Ed Catmull, along with his colleagues Robert L. Cook and Loren Carpenter at Pixar, received an Academy Award of Merit “for significant advancements to the field of motion picture rendering as exemplified in Pixar's RenderMan.”

In 2015, the traveling exhibit *The Science Behind Pixar* opened as a collaboration between Pixar and the Boston Museum of Science. The exhibit showcased the science, technology, engineering, art, and mathematics (STEAM) that Pixar uses to create its films. The exhibit is organized around Pixar's production pipeline and includes content on modeling, rigging, surfaces, sets and cameras, animation, simulation, lighting, and rendering. Related is Pixar's partnership with the NSF on a research project to help educate people about computational thinking. Leveraging six exhibit experiences from *The Science Behind Pixar*, the aim is to help students learn how to break down a challenge into pieces that can be understood and carried out by a computer.

SEE ALSO Sketchpad (1963)

A collection of popular films from Pixar Animation Studios.





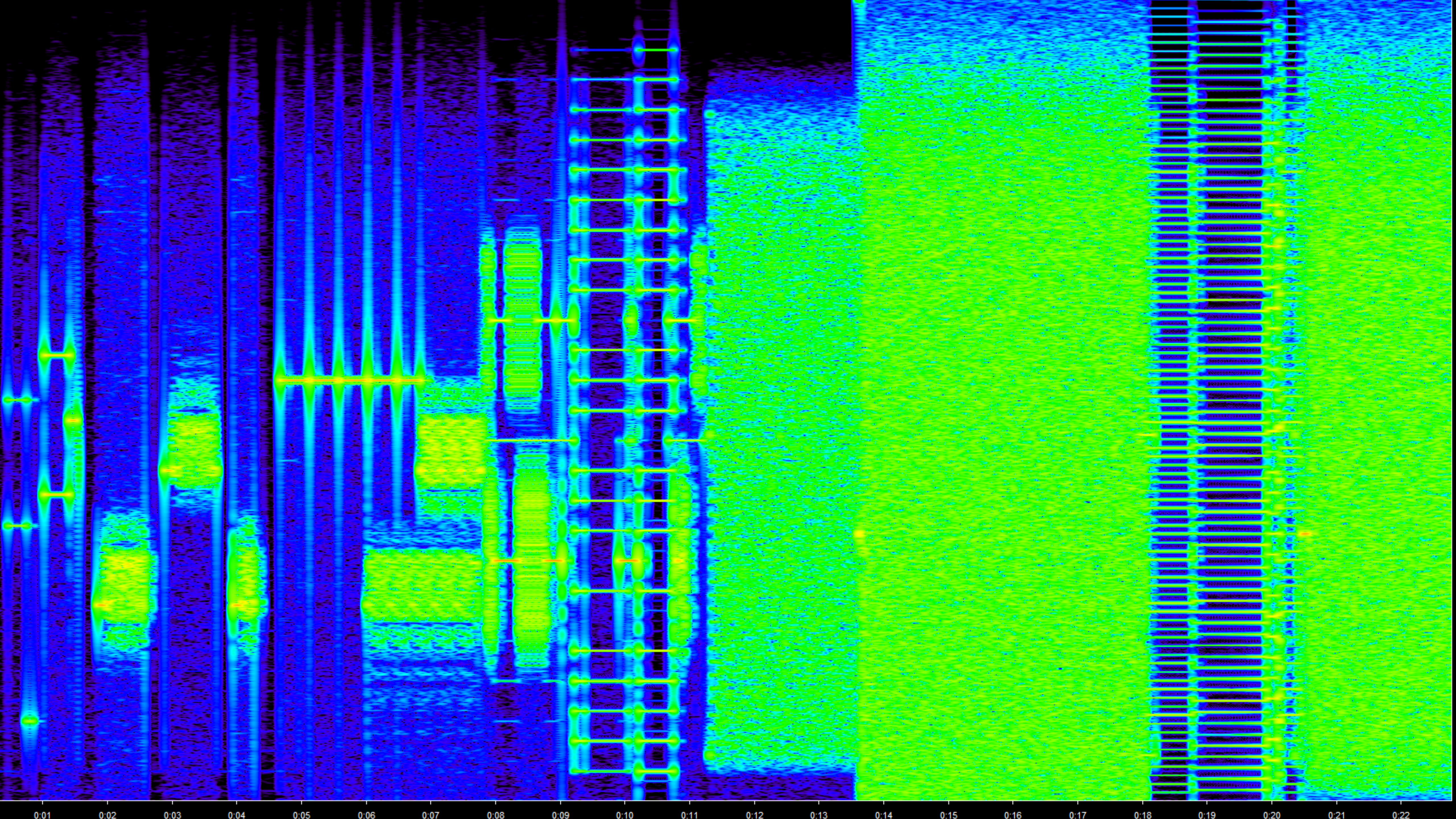
Sometimes we got the
photos ourselves!

Telebit modem (wikiwand)



Telebit T3000 (Wikipedia)





Telebit Modems Break 9600 bps

The TrailBlazer modem, from the US-based company Telebit, was a computer-networking breakthrough. In 1984, at a time when most dial-up computer users were just beginning to make the transition from modems that could send 1200 bits per second (bps) to those that could send 2400 bps, Telebit introduced a modem that could transfer data over an ordinary phone line at speeds between 14,400 and 19,200 bits per second.

The secret to the TrailBlazer's speed was its proprietary channel-measuring protocol. At the time, phone calls traveled over many analog wires to reach from one end to another, creating something communications engineers called a *channel*, and every channel was slightly different. Telebit's Packetized Ensemble Protocol (PEP) divided that channel into 512 different analog slots. When one TrailBlazer sensed it was communicating with another, the two modems would measure the channel and determine which of those slots could be used for high-speed data transfer. In any given instance, the modems would allot the majority of slots to the modem transferring the most data. The TrailBlazer also had direct support for the UNIX-to-UNIX-Copy protocol (UUCP), making it a hit with Usenet sites.

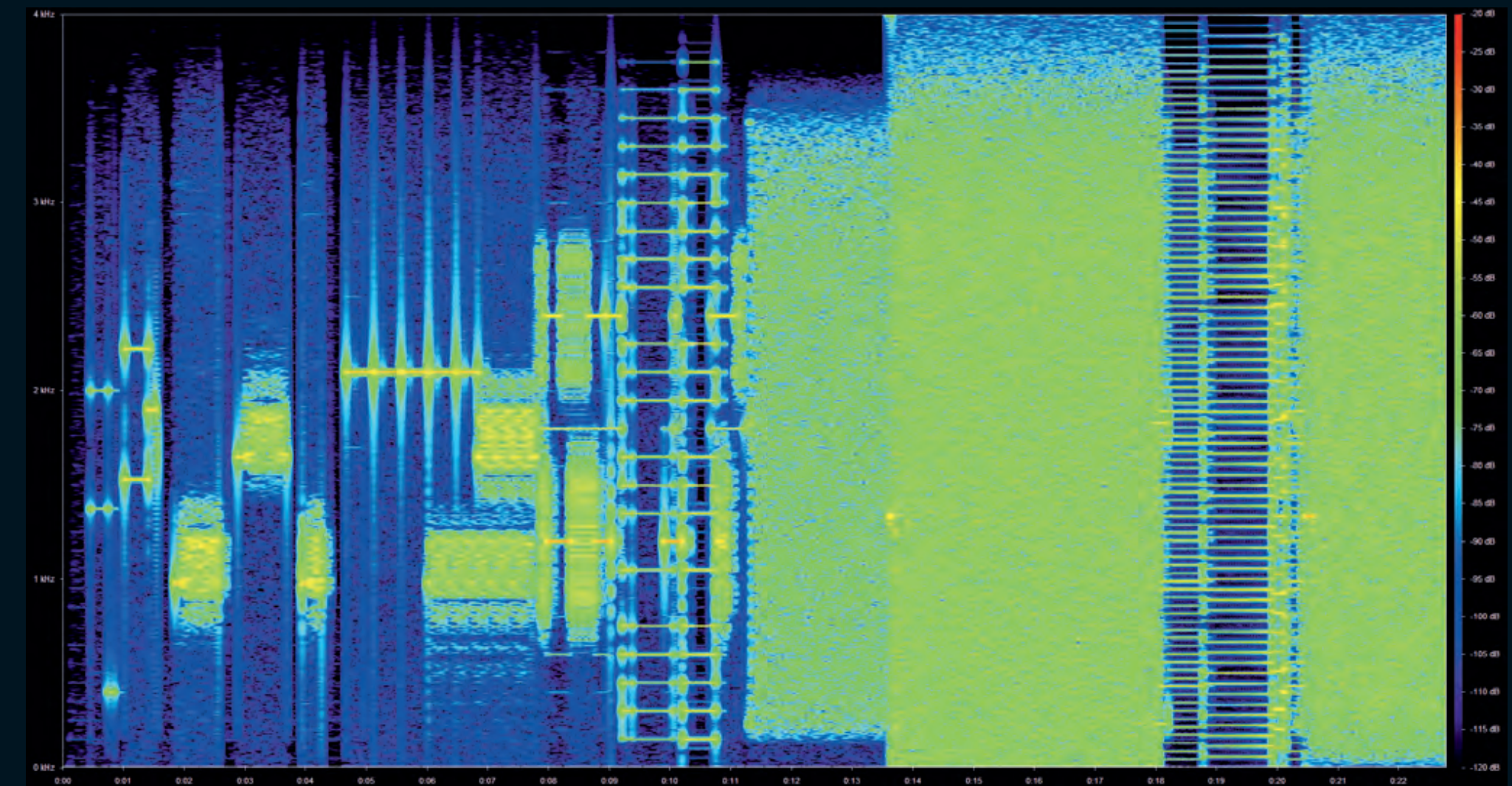
In 1985, each TrailBlazer cost \$2,395. The modems frequently paid for themselves in the first year, however, through savings on long-distance charges.

The TrailBlazer triggered what came to be known as the “modem wars.” They started when Telebit's primary competitor, US Robotics Corporation®, introduced its own 9600 bits per second modem for \$995 in 1986. The two modems were not compatible. Telebit responded by slashing the price of the TrailBlazer to \$1,345 in 1987.

The industry knew the path to riches would come only from a larger, multivendor market—and that required standardization. The first high-speed standard was the V.32 9600 bits per second in 1987; prices for external models dropped to \$400. A succession of faster and lower-priced models followed until, finally, the International Telecommunication Union (ITU) released the draft V.90 standard in February 1998, which supported 56-kilobit-per-second download speeds to consumers from specially equipped internet service providers (ISPs). This was as fast as was theoretically possible over an analog phone line without the use of compression.

SEE ALSO The Bell 101 Modem (1958), Usenet (1980), PalmPilot (1997)

This spectrograph shows the tones made by a pair of modems during the first 22 seconds of a particular high-speed connection.

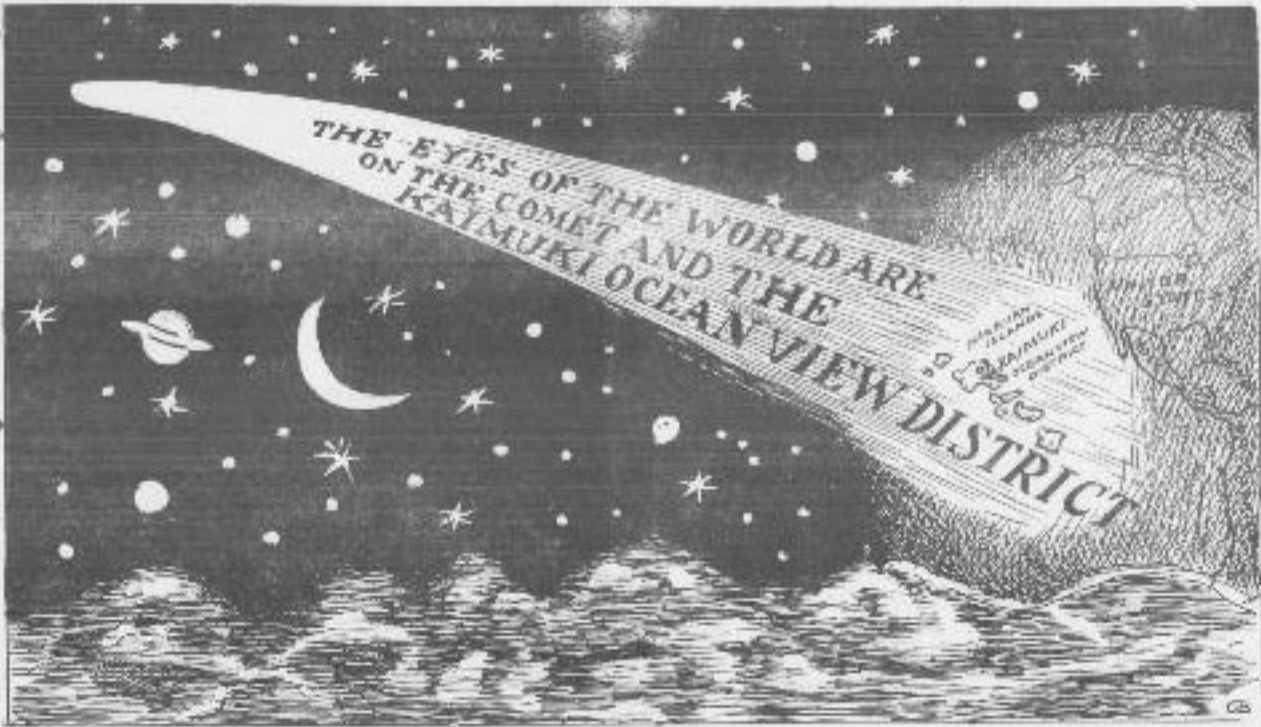




THE HAWAIIAN STAR. SATURDAY, APRIL 16, 1910. THREE

HALLEY'S COMET.

Rises over Koko Head every morning at 4 o'clock adding to the magnificent scenery of the OCEAN VIEW DISTRICT. A grand sight may now be seen from the beautiful District where the atmosphere is purest, and the ocean breeze the coolest.



GO OUT AND TAKE A LOOK.

The opportunity of your life to see Halley's Comet and buy OCEAN VIEW Property at reasonable prices. When the Comet leaves, it will be absent for seventy-five years and when Honolulu becomes a great American city, you will never again be able to buy OCEAN VIEW Property at the low prices and reasonable terms that we offering today. All those who have brought and are interested in buying property will be given a free automobile ride in time to see the Comet through the observatory. We have automobile leaving the Hotel Street entrance of the Young Hotel every morning at 3:30. Call at our office or ring up Telephone. 659 and make an appointment.

The Ocean View District

AN IDEAL PLACE TO LIVE

ARTESIAN WATER, HIGH ELEVATION, PAVED STREETS, KOKO HEAD BREEZE.
ELECTRIC LIGHTS, DELICIOUS CLIMATE, SUFFICIENT RAINFALL, EXCELLENT SOIL.
LEVEL PROPERTY, COOL AND HEALTHFUL, GOOD LOCATION, PURE ATMOSPHERE.

Take the Waialeale car, and upon your arrival at Kaimuki call on our branch office in charge of E. L. Henderson, who will be pleased to show you the property and supply you with maps, literature and all the information you may require. Our fixed prices are \$250 for corner lots and \$400 for inside lots, size 75 ft. x 150 ft. or 11,250 sq. ft. each. Our terms are \$25 cash down and \$10.00 per month on 60% bal.

Kaimuki Land Company, Ltd.,

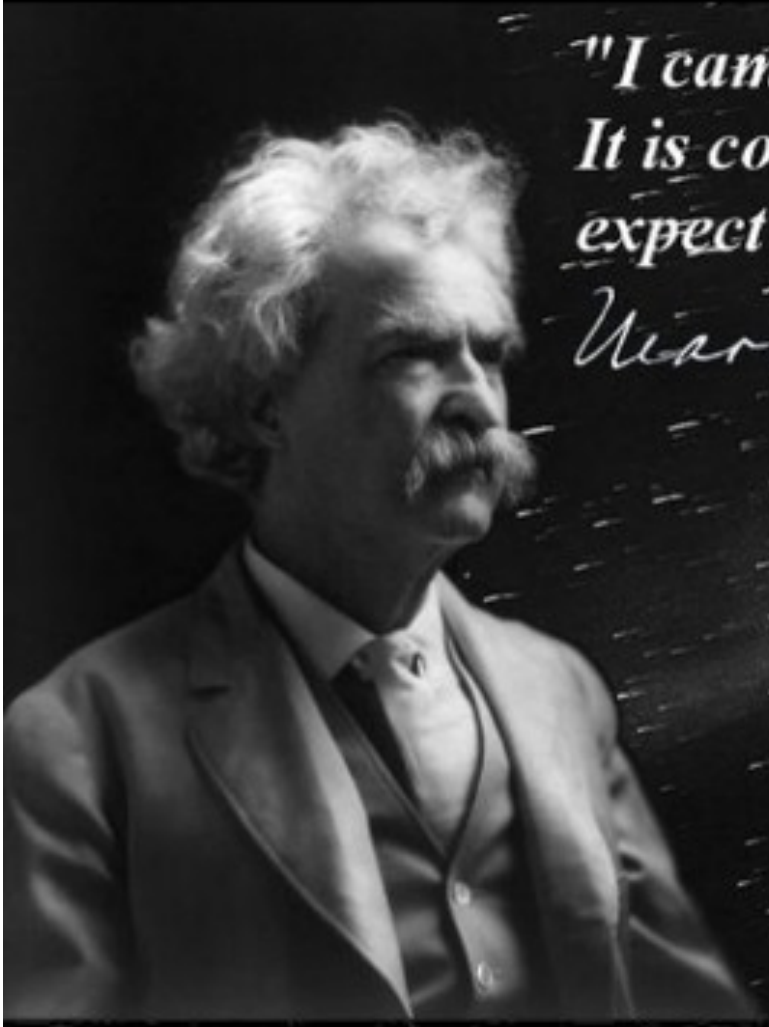
Main Office: King and Fort Sts. Phone 659 Branch Office: Waiānae and Koko Head Aves

tion will be restored for another month.

COMING END OF WORLD

Halley's Comet May Snuff Out Life on the Earth

Berkeley, Cal., Feb. 9.—"If the astronomers are right in their estimations of the amount of cyanogen gas in the tail of Halley's comet, and if that body's vapors do envelop the earth, we may have a chance to feel the sensations of the bugs and insects which are killed by the use of this deadly gas as an exterminator."

"I came in with Halley's Comet in 1835. It is coming again next year, and I expect to go out with it."

Mark Twain

Mark Twain passed away on April 21, 1910, one day after Halley's return

1758

Human Computers Predict Halley's Comet

Edmond Halley (1656–1742), **Alexis-Claude Clairaut** (1713–1765),
Joseph Jérôme Lalande (1732–1807), **Nicole-Reine Lepaute** (1723–1788)

The discovery of Kepler's laws of planetary motion and Isaac Newton's more general laws of motion and gravity encouraged scientists to seek elegant mathematical models to describe the world around them. Edmond Halley, the editor of Newton's *Principia* (1687), used Newton's calculus and laws to show that a comet seen in the night sky in 1531 and 1682 must be the same object. Halley's work depended on the fact that the comet's orbit was influenced not just by the sun, but also by the other planets in the solar system—especially Jupiter and Saturn. But Halley could not come up with an exact set of equations to describe the comet's trajectory.

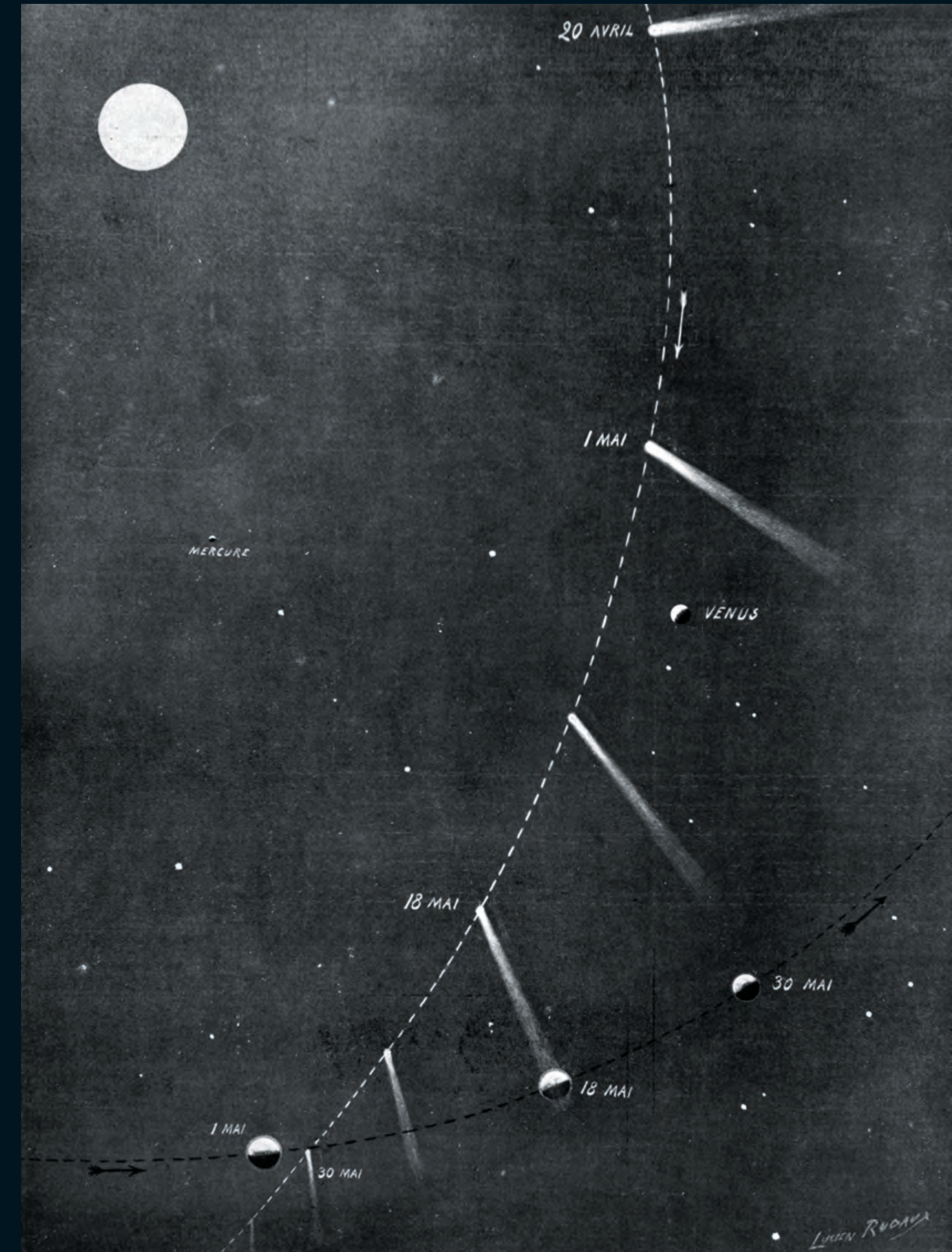
Alexis-Claude Clairaut was a French mathematician who devised a clever solution to the problem. But it wasn't mathematically elegant: instead of solving the problem symbolically, his method solved the problem numerically—that is, with a series of arithmetic calculations. He worked with two friends, Joseph Jérôme Lalande and Nicole-Reine Lepaute, during the summer of 1758, and the three systematically plotted the course of the comet, calculating the wanderer's return to within 31 days.

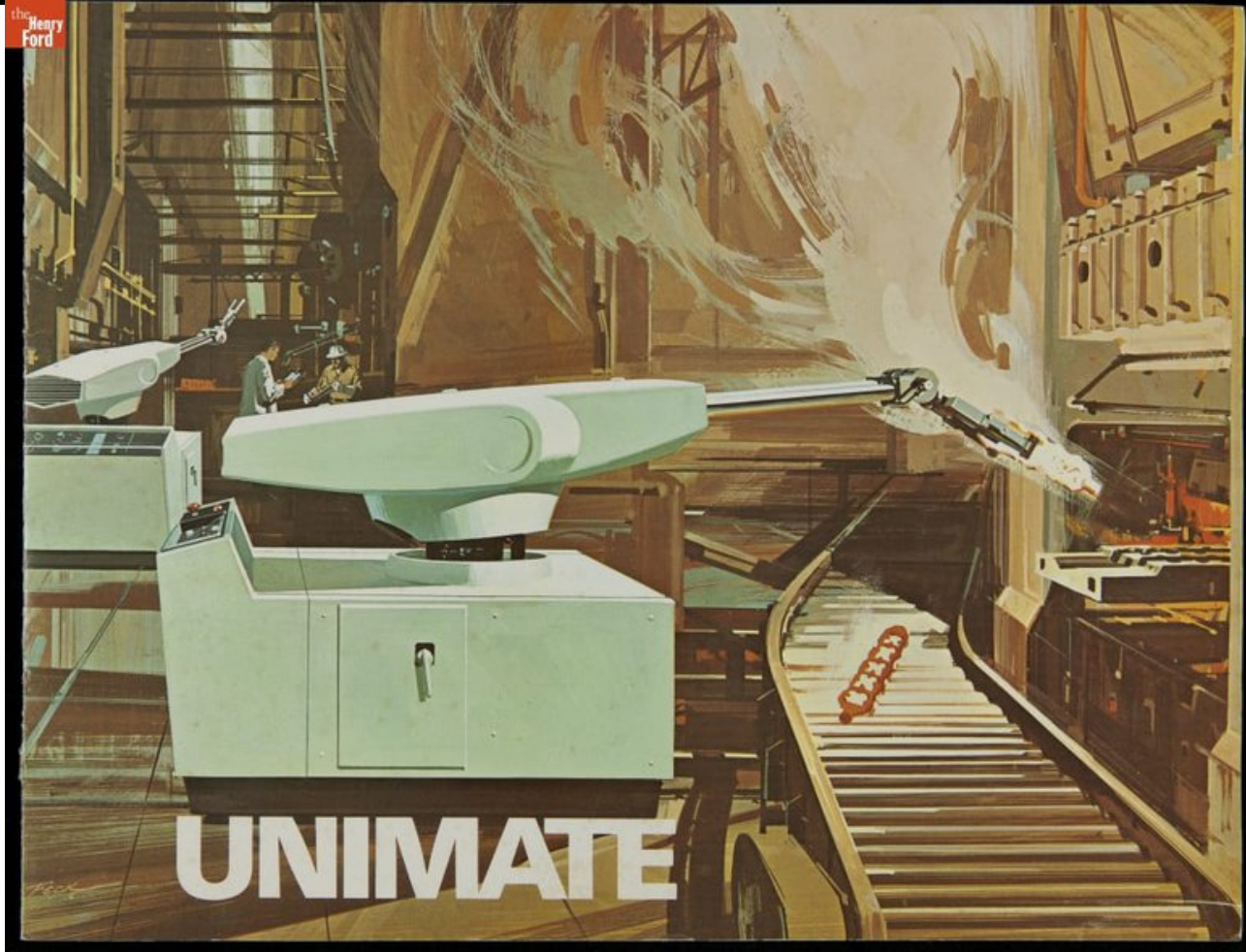
This approach of using numerical calculations to solve hard science problems quickly caught on. In 1759, Lalande and Lepaute were hired by the French Académie des Sciences to contribute computations to the *Connaissance des Temps*, the official French almanac; five years later, the English government hired six human computers to create its own almanac. These printed tables charted the anticipated positions of the stars and planets and were the basis of celestial navigation, allowing the European powers to build out their colonies.

In 1791, Gaspard Clair François Marie Riche de Prony (1755–1839) embarked on the largest human computation project to that date: to create a 19-volume set of trigonometric and logarithmic tables for the French government. The project took six years and required 96 human computers.

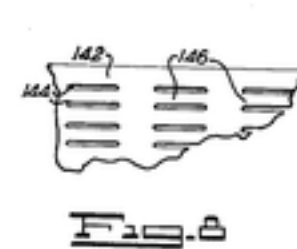
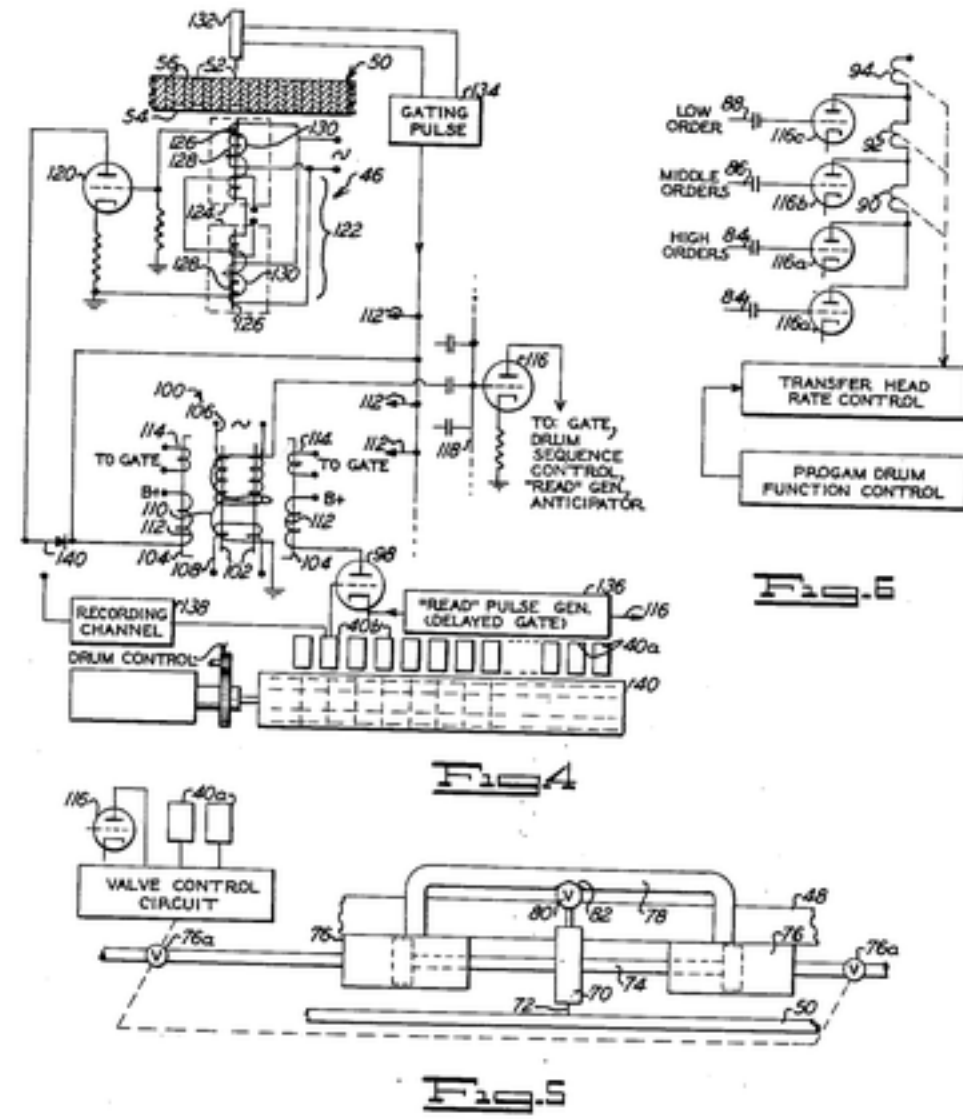
SEE ALSO First Recorded Use of the Word *Computer* (1613)

The course of Halley's Comet across the night sky from April through May of 1910.





June 13, 1961 G. C. DEVOL, JR 2,988,237
 PROGRAMMED ARTICLE TRANSFER
 Filed Dec. 10, 1954 3 Sheets-Sheet 2



1961

Unimate: First Mass-Produced Robot

George Devol (1912–2011), Joseph F. Engelberger (1925–2015)

After seeing a picture of assembly-line workers in a technical journal, American inventor George Devol wondered if there could be a tool to replace the repetitive, mind-numbing tasks people had to perform. This question led him to design something akin to a mechanical arm, which he patented in 1961, called the *Programmed Article Transfer device*.

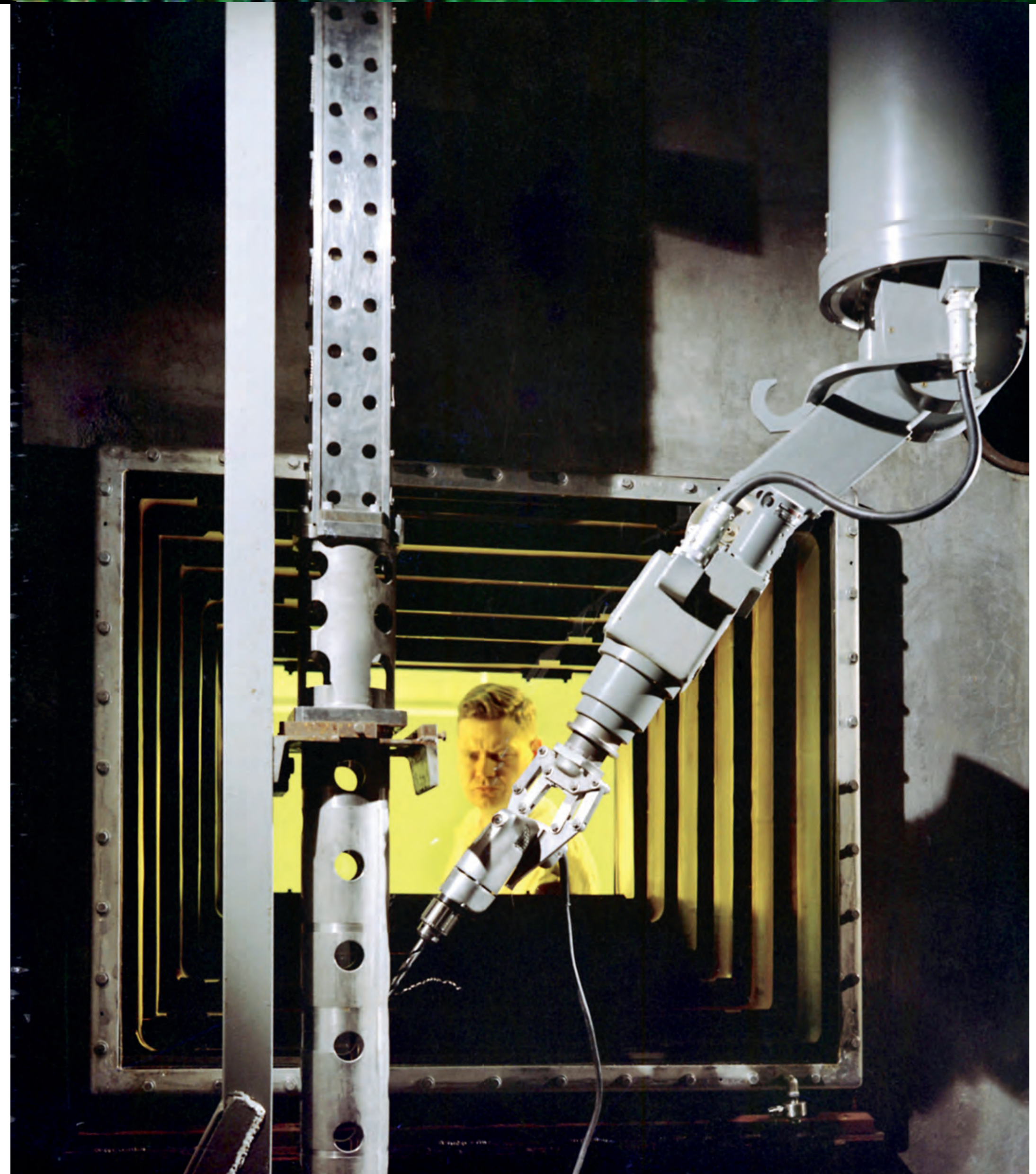
Devol had a fortuitous introduction to engineer and businessman Joseph Engelberger at a cocktail party in 1956. Engelberger, fascinated by Isaac Asimov's robot stories, immediately recognized the business potential of Devol's "robot" device. As business partners, they had to perfect the device and convince others to buy it. Engelberger's sales strategy was to identify jobs that Unimate (the name suggested by Devol's wife, Evelyn) could do that were dangerous or difficult for humans to perform. General Motors® (GM) was the first to buy into the idea, and in 1959 the Unimate #001 prototype was installed in an assembly line in Trenton, New Jersey. Unimate's job was to pick up hot door handles that had just been made from molten steel and drop them into cooling liquid before they were sent down the line for human workers to finish polishing. The Unimate would go on to spawn new industries and revolutionize production and manufacturing plants around the world.

The Unimate weighed 4,000 pounds (1,814 kilograms) and was controlled by a series of hydraulics. Memory was stored on a magnetic drum, and pressure sensors inside the arm enabled it to adjust the strength of its grip as needed. Unimate "learned" a job by first having a person manually move its parts in the sequence of steps desired to complete the task. The movements were recorded by its computer and then simply repeated over again.

In 1966, Unimate was featured on *The Tonight Show Starring Johnny Carson*, where it demonstrated how it could knock a golf ball into a hole, pour a can of beer, and conduct the *Tonight Show* orchestra. An early model of this robot can be found at the Smithsonian's National Museum of American History; in 2003, the Unimate was inducted into the Carnegie Mellon Robot Hall of Fame.

SEE ALSO Isaac Asimov's Three Laws of Robotics (1942)

This 52-inch (1.3-meter) -thick, oil-filled glass window protects a nuclear engineer from radiation while he operates a robotic arm at NASA's Plum Brook Station in Sandusky, Ohio, 1961.





Google Releases TensorFlow

Makoto Koike (dates unavailable)

Cucumbers are a big culinary deal in Japan. The amount of work that goes into growing them can be repetitive and laborious, such as the task of hand-sorting them for quality based on size, shape, color, and prickles. An embedded-systems designer who happens to be the son of a cucumber farmer (and future inheritor of the cucumber farm) had the novel idea of automating his mother's nine-category sorting process with a sorting robot (that he designed) and some fancy machine learning (ML) algorithms. With Google's release of its open source machine learning library, TensorFlow®, Makoto Koike was able to do just that.

TensorFlow, a deep learning neural network, evolved from Google's DistBelief, a proprietary machine learning system that the company used for a variety of its applications. (Machine learning allows computers to find relationships and perform classifications without being explicitly programmed regarding the details.) While TensorFlow was not the first open source library for machine learning, its release was important for a few reasons. First, the code was easier to read and implement than most of the other platforms out there. Second, it used Python, an easy-to-use computer language widely taught in schools, yet powerful enough for many scientific computing and machine learning tasks. TensorFlow also had great support, documentation, and a dynamic visualization tool, and it was as practical to use for research as it was for production. It ran on a variety of hardware, from high-powered supercomputers to mobile phones. And it certainly didn't hurt that it was a product of one of the world's behemoth tech companies whose most valuable asset is the gasoline that fuels ML and AI—data.

These factors helped to drive TensorFlow's popularity. The greater the number of people using it, the faster it improved, and the more areas in which it was applied. This was a good thing for the entire AI industry. Allowing code to be open source and sharing knowledge and data from disparate domains and industries is what the field needed (and still needs) to move forward. TensorFlow's reach and usability helped democratize experimentation and deployment of AI and ML applications. Rather than being exclusive to companies and research institutions, AI and ML capabilities were now in reach of individual consumers—such as cucumber farmers.

SEE ALSO GNU Manifesto (1985), Computer Beats Master at Go (2016), Artificial General Intelligence (AGI) (~2050)

TensorFlow's hallucinogenic images show the kinds of mathematical structures that neural networks construct in order to recognize and classify images.



Closing thoughts on photos

Some photos chosen for one milestone were used for another.

Many photos have insufficient metadata.

Publicity photos can be surprisingly good.

Many stock photos have similar feel



The background of the slide features a dark blue field with intricate, wavy patterns in shades of green and teal. A large, bold, yellow number '5' is centered on the slide.

5

Q&A

Never end a presentation with a slide that says “Questions.”

Time spent negotiating is time lost to writing

June 2, 2016 — Initial email; November 2017 deliverable.

April 12, 2017 — Signed contract, new-co-author, same delivery date

November 2017 — Deliverable met

Budgets are real but they matter in unexpected ways

It's hard to write a (good) 350-word essay about a historic topic.

Credibility is easily damaged if you get something wrong that other people know.

Deep research is fun, but it doesn't get the project to done.