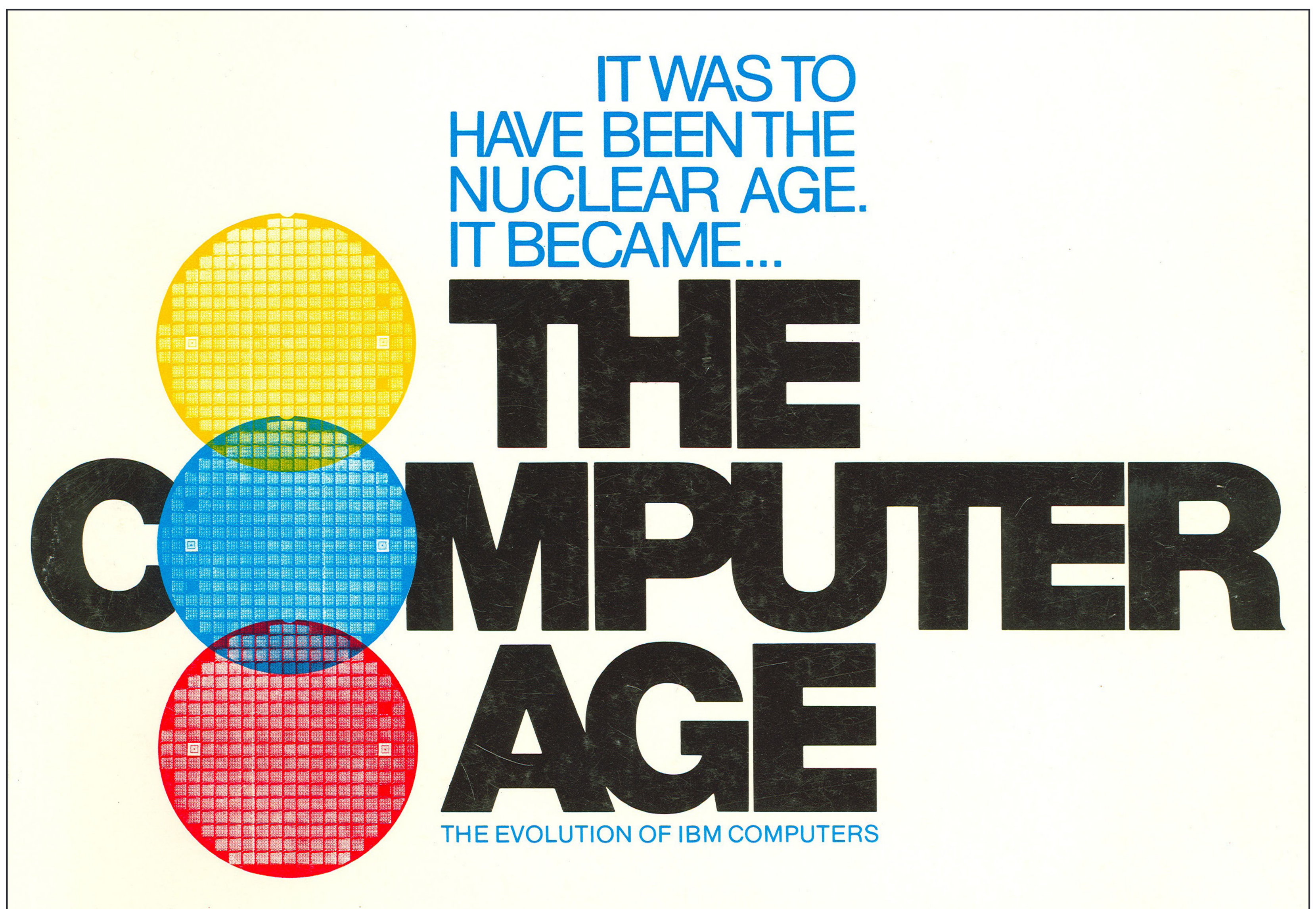
MAKING *the* MODERN WORLD

Public-Private Partnerships and Advancements in Science and Technology from 1955 to 1975

PART 1 OF 4



The front page of an IBM four panel advertisement released in 1976, highlighting computers at the expense of the nuclear age. In truth, the two were inextricably linked. Fear of the Cold War escalating into nuclear conflict led the U.S. government to exponentially advance microchip technology to gain an edge in the space race and conventional armaments. These digital advancements soon cascaded into civil society. (Courtesy of the Computer History Museum)

Public-private partnerships in medicine from the 1950s through the 1970s incentivized exchanges in science, technology, and medical practices to the great benefit of public health and private healthcare alike. Medical knowledge exponentially increased as a result and, by the 1970s, the U.S. saw the beginnings of medical centers of excellence with specialized expertise in medical research, education, and care. (Courtesy of National Museum for Health and Medicine)

In the early fifties, it was the DoD that supported transistors by buying them for the guidance systems of its rockets and missiles. The computerization of society, then, has essentially been a side effect of the computerization of war.

-Frank Rose, *Digital Anthropologist*

INTRODUCTION

In the aftermath of World War II, the United States and Soviet Union emerged as the globe's two superpowers. Locked in an ideological zero-sum game, each possessed long-range bombers, aircraft carriers, missiles, and nuclear firepower that nullified the safety once granted by the lands and oceans between them. The world shrank dramatically as a result. Armed with atomic firepower, humanity was now capable of self-destruction.

Throughout the Cold War, the U.S. made the deliberate choice to limit the size of its military, and instead depended upon allies, the nation's own economic might, and developing technological superiority in conventional armaments to limit conflict. U.S. leaders believed war would need to be tightly controlled to avoid nuclear devastation, and limiting it framed every aspect of the Cold War. Even where the U.S. engaged in military action, the nation made self-limiting decisions. For instance, during the Vietnam War, the United States made the deliberate choice not to invade North Vietnam to avoid antagonizing nuclear capable China and the Soviet Union.

Scientific learning and expertise brought the world into the nuclear age; the United States Federal Government once again turned to scientific expertise to safeguard the nation. Yet innovation alone was not enough; national defense demanded the expeditious deployment of advancements in science, medicine, and technology to enhance the nation's global readiness. Even as scientific and technological enhancements were put into operation, national security necessitated the scientific community continue to refine its work to exponentially increase the rate by which knowledge could be harnessed. To achieve this end, the Federal Government and military branches of service streamlined public-private partnerships, which are collaborations between government and non-government entities. These partnerships created a pipeline between public sector officials who funded research and experts outside of government who required only the means to realize their ideas. This arrangement established a process that minimized the time from technology's inception to its deployment.

Much of this work was performed during the Vietnam War period from 1955 to 1975. During this time, public-private partnerships advanced science, medicine, and technology in ways that profoundly shaped our modern world.

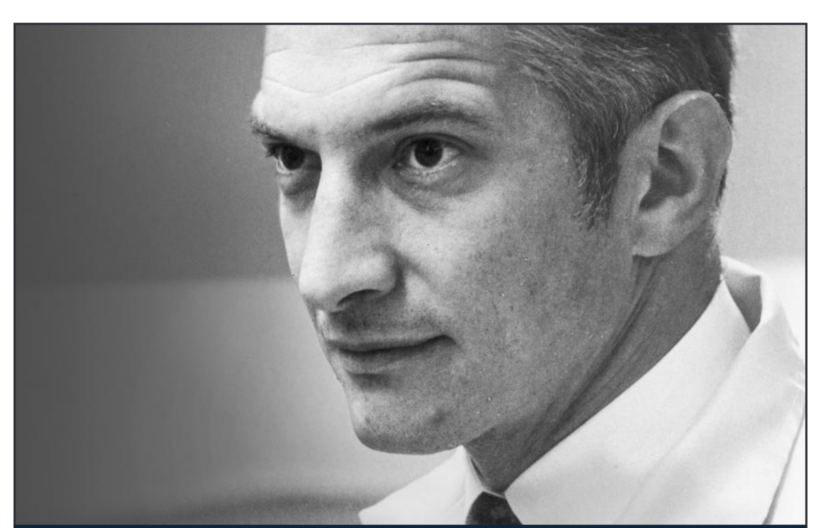
THE DIGITAL COMPUTER

The modern digital computer's development was the cornerstone upon which all future scientific, medical, and technological developments were built. Faster and more powerful computers enabled greater advances at increasing speeds in all aspects of human life. In the 1950s, digital computers began to replace their much slower and inefficient analog predecessors, which brought about the nascent beginnings of the digital, media, and information revolution.

From 1949 to 1959, nearly 60% of corporate funding in computer development came from the U.S. government. Major corporations developing computer hardware included IBM, General Electric, Bell Laboratories, the Fairchild Semiconductor Corporation, and Texas Instruments, among others. They were bankrolled by the U.S. government and tasked with developing smaller and more powerful electronics to strengthen national defense.

By the late fifties, hardware engineers Egyptian-American Mohamed Attalla and Korean-American Dawon Kahng, partners at Bell Laboratories, invented the metal-oxide-silicon field-effect transistor. This device became the basis of modern electronics. At the same time, working for Texas Instruments, American electrical engineer Jack Kilby developed the first hybrid integrated circuit from germanium. When American physicist Robert Noyce cofounded the Fairchild Semiconductor Corporation in Mountain View, California, he examined Kilby's invention and concluded the device required some refinement to be mass produced. Noyce and his team went to work creating the world's first monolithic integrated circuit chip using silicon. They drew from methods developed by Attala and Kahng. With Fairchild's development of a silicon microchip, the California valley's namesake began in earnest.

The implications of the digital future quickly became far greater than the military sphere alone. For instance, in the early 1960s, the newly formed National Aeronautics and Space Administration (NASA) attracted scientists from the U.S. military's rocketry programs to develop spacecraft capable of reaching the moon. From 1961 to 1965, NASA was the single largest consumer of mass-produced integrated circuits. In 1965, Noyce's colleague, Gordon Moore, was asked by *Electronics Magazine* to forecast the future of computers. Moore anticipated a kind of snowballing effect. He predicted electronics would exponentially increase in power. His response became the basis for what is today referred to as *Moore's Law.*



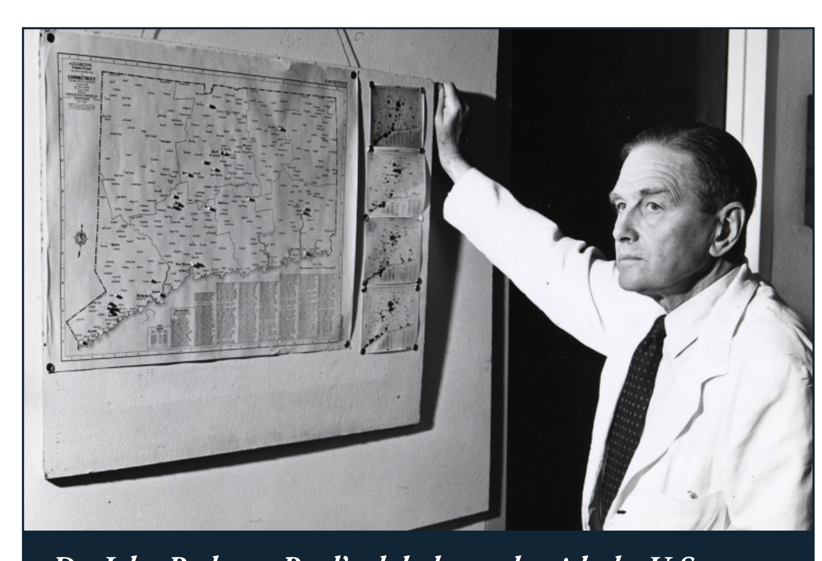
Robert Noyce co-founded Fairchild Semiconductor and the Intel Corporation in 1957 and 1968, respectively. Noyce engaged in public-private partnerships throughout his professional life, during which he co-invented the integrated circuit and used silicon to advance microchip technology. In 1987, three years prior to his death, Noyce became the first head of Semiconductor Manufacturing Technology (SEMATECH), a non-profit consortium and partnership between the U.S. government and 14 U.S.-based semiconductor manufacturers. For more than five years at the cost of $500 million, the consortium was funded in part by Department of Defense subsidies. (Courtesy of the Intel Corporation)

Moore's Law proved correct. 1950s public-private partnership successes fueled private-sector growth. Private demand for digital computers grew, and so did their reliability, intricacy, capability, and power. Hardware advancements subsequently required more powerful and complex software to run them. As a result, programming languages advanced at a remarkable pace as well. By 1972, Bell Laboratories introduced the language C, which runs many modern desktop applications, including video games, e-commerce, web searches, and operating systems.

FROZEN BLOOD

Fearing an apocalyptic nuclear war and wishing to capitalize on the growing capabilities of digital computing, experts in biomedicine sought to create repositories of human blood. With blood properly stored, frozen, and preserved, experts created an archive of humanity from which to conduct future study.

Like many of his peers in the 1930s, 40s, and 50s, Yale epidemiologist John Rodman Paul devoted his energies to the study of poliomyelitis (Polio), which is an especially virulent disease of the central nervous system that left many children temporarily or permanently paralyzed. During World War II, Paul served as director of the Neurotropic Virus Disease Commission of the Armed Forces Epidemiological Board (AFEB). The U.S. military tasked the board with studying global medical health challenges. Paul traveled to Egypt and confirmed polio infections among U.S. and British troops. Though the disease was unknown among the adult Egyptian population, Paul hypothesized that young Egyptian children had acquired immunity following an early exposure to the virus. Following the war, Paul partnered with the U.S. Navy to visit indigenous populations in outlying American regions, where he drew and froze their blood. From these studies, he discovered that a single experience with Polio resulted in lifelong immunity. His research proved essential to the development of the polio vaccine.



Dr. John Rodman Paul's global travels with the U.S. Armed Forces Epidemiological Board led Rodman to methodologically map diseases' passage through human civilization. By the 1960s, his methodology and newly acquired technologies made it possible for the World Health Organization to adopt his serological surveillance program. (Courtesy of Yale University Library)

CONCLUSION

Public-private partnerships laid the foundation for future global success. In July 1968, Robert Noyce and Gordon Moore left Fairchild Semiconductor and founded the Intel Corporation. In 1969, Jerry Sanders left Fairchild Semiconductor and founded Advanced Micro Devices, or AMD, which remains a principal competitor of Intel to this day. For his part, John Rodman Paul used his experiences with indigenous populations to justify a broader program of serological (or blood) surveillance that was ultimately adopted by the World Health Organization. From 1961 to 1966, Paul served as the director of the World Health Organization Serum Reference Bank located in the Yale Department of Epidemiology and Public Health.

MAKING *the* MODERN WORLD

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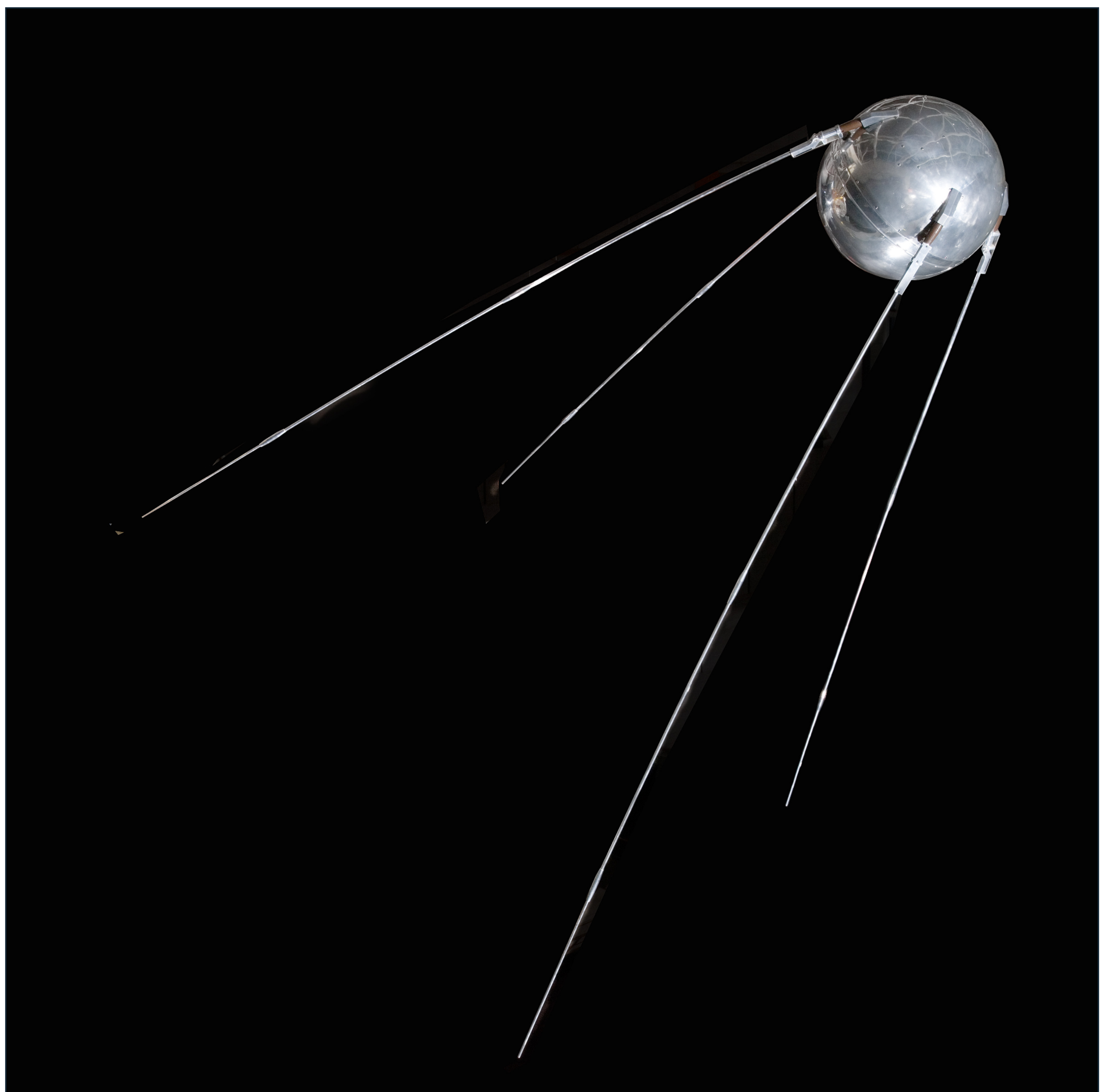
PART 2 OF 4



The Cold War was a global and political battleground that framed all aspects of civil life. When the Soviet Union launched Sputnik, *many U.S. citizens feared the nation had lost its technological edge. In his presidential campaign, John F. Kennedy seized on these anxieties. He promised to close the gap between the two nations and place a U.S. astronaut on the moon. (Courtesy of the Smithsonian Air and Space Museum)*

Oh little Sputnik flying high with made-in-Moscow beep, you tell the world it's a Commie sky and Uncle Sam's asleep.

– Gerhard Mennen Williams, *Governor of Michigan*

INTRODUCTION

On October 4, 1957, the Soviet space program launched *Sputnik 1* into Earth's orbit. The 184-pound satellite roughly the size of a beach ball shattered the globe's presumption that the Soviet Union was a technologically inept and underdeveloped state. Though U.S. officials minimized *Sputnik's* launch publicly, the Federal Government quietly and quickly went to work establishing the Advanced Research Projects Agency (ARPA) within the Department of Defense. Formed in February of 1958, ARPA was tasked with directing public-private partnerships to close the technological gap. ARPA collaborated with experts in academia, industry, and other government agencies on research and development projects to push the frontiers of technology and science.

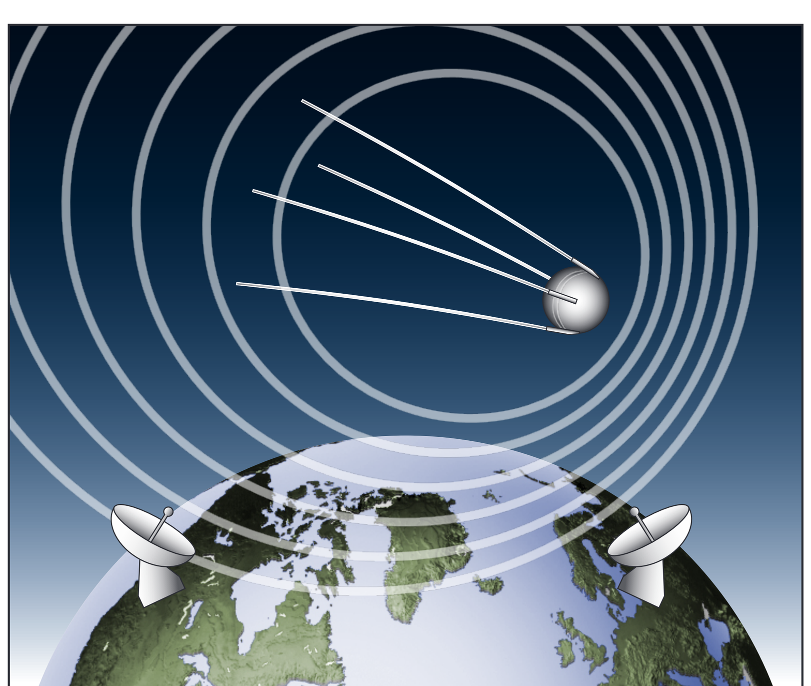
Among its many projects, the agency was particularly interested in the development and deployment of U.S. satellites. Little did ARPA know, a battery and radio transmitter inside *Sputnik 1* held the keys to realizing the agency's goals, and with them, a new way of envisioning humanity's navigational relationship to the world.

For 21 days following its launch, *Sputnik 1* transmitted radio signals. Among those listening were two American physicists, William Guier and George Weiffenbach, who worked at the Johns Hopkins University's Applied Physics Laboratory (APL).

THE GLOBAL POSITIONING SYSTEM

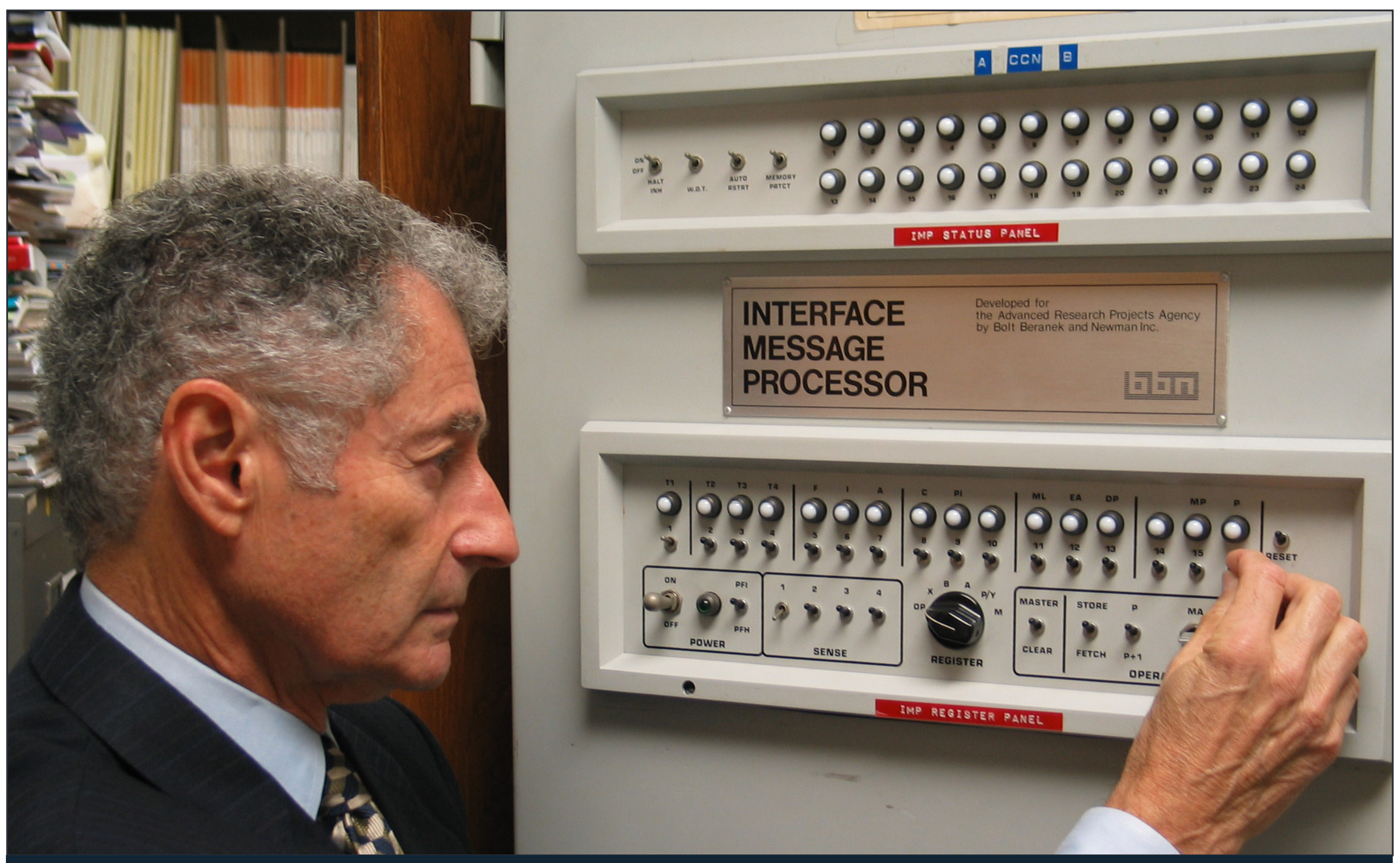
As William Guier and George Weiffenbach listened to *Sputnik 1* orbit the planet, they observed a strange phenomenon: The frequency of radio signals transmitted increased as the satellite approached, and the signal decreased as the satellite moved away. Here was the Doppler Effect in action. Listening, they tracked the satellite's movement.

The two had a moment of revelation and later wrote, "We could positively identify [*Sputnik 1*] as a near Earth satellite!" They honed their efforts, quantified the Doppler data, and, with the aid of other physicists and improvements to their equipment—to include a newly acquired UNIVAC 1200F digital computer—they were able to predict the satellite's orbit.



The Doppler effect, or the Doppler shift as it sometimes is referred, describes the changes in occurrence of sound or light produced by the emitter with respect to its observer. Waves produced by an object traveling toward the observer occur at a higher frequency than waves emitted by the source traveling away from the observer. In day-to-day life, we note this with a passing emergency vehicle's siren. (Courtesy of the Office of the Secretary of Defense)

Guier and Weiffenbach later wrote that on March 17, 1958, Frank McClure, the deputy director of APL, "called us to his office and asked us to close the door." Sensing his query, the two physicists began work on determining the inverse: Could the receiver of a signal determine its own position from a satellite signal in a known orbit?



Dr. Leonard Kleinrock at the Interface Message Processor that sent the first internet transmission in 1969. Kleinrock was instrumental in the development of ARPANET. The first message was sent by a UCLA student, Charley Kline, who Kleinrock supervised. The message text was "login;" however, the system crashed following the "l" and the "o" letters, effectively making "lo" the first message transmitted over ARPANET. An hour later, with the system restored, the full "login" was retrieved. (Courtesy of the UCLA Samueli School of Engineering).

McClure persuaded a colleague at John Hopkins, a brilliant mathematician named Richard Kershner, to design a system of satellites that would transmit navigational information to the U.S. Navy. They developed the Navy Navigation Satellite System (NNSS, sometimes called NAVSAT), which they colloquially referred to as Transit. ARPA funded the Transit program in 1958 and Transit launched its first satellite by 1960. By 1968, a fully operational constellation of 36 satellites was in place. The Transit system provided accurate, all-weather navigation to both military and commercial vessels, including the U.S. Navy's ballistic missile submarine force. Transit established the basis for wide acceptance of satellite navigation systems, yet was nevertheless limited in its capabilities.

In the early 1970s, the U.S. Air Force selected Colonel Bradley Parkinson to become director of the vaguely named Joint Program Office (JPO) to head up the equally ambiguously named fledgling project 621B (later called NAVSTAR), which was tasked with launching a more accurate system of global positioning satellites into orbit. Parkinson quickly got to work putting a team of talented military and civilian experts together. By June 1974, his office selected Rockwell International as the satellite contractor. The JPO oversaw the deployment of the first operational prototype in February 1978 at the Army's Yuma proving ground in Arizona.

NETWORKED COMPUTERS

While experts feverishly worked to create networked navigational systems from space, networking computers back on earth proved equally popular; yet ironically, networked computing came about because of two experts who independently came to the same idea during the 1960s. Welsh computer scientist Donald Davies and Polish-American computer engineer Paul Baran separately proposed "packet switching," which is a method of grouping data into packages that are then transmitted over a digital network. While working for the RAND Corporation, which is short for "Research and Development," Baran explained his vision for networked computers in *On Distributed Communications*, which he published in 1964. To provide for the defense of the United States if war ever arrived on its soil, ARPA was attempting to tie an array of defense computers together into a network called ARPANET. Yet Baran's ideas were unknown to them. In October 1967, Davies' presentation at a "Symposium on Operating Systems Principles," caught the attention of ARPA. Using Davies' ideas and Baran's direction, ARPA began the development of ARPANET in earnest. In 1969, Baran's "distributed" concept was given its first large-scale test, with the first node installed at UCLA and the seventh node at RAND in Santa Monica.

By 1972, American electrical engineer Robert Kahn joined the Information Processing Techniques Office (IPTO) within DARPA. That fall he demonstrated ARPANET by connecting 20 different computers at the International Computer Communication Conference. He later developed the TCP/IP protocols for connecting diverse computer networks. When connected, those networks formed the basis for the Internet.

The delivery of the Scientific Data Systems (SDS) Sigma 7 computer to Boelter Hall at UCLA in 1967. SDS machines were early adopters of integrated circuits and silicon transistors; yet, despite this, their machines still contained considerable heft. To deliver this unit, a hole was cut into the outside wall of the building, where a forklift elevated the machine to its destination. (Courtesy of the UCLA Samueli School of Engineering)

Fittingly, some of Baran's last communications with Davies were e-mails written in 2000, a few months before Davies' death. In the spirit of collaboration, Baran stated, "You and I share a common view of what packet switching is all about, since you and I independently came up with the same ingredient. I view your effort as totally independently coming up with the notion of packet switching, naming it and being the first to reduce it to practice."

CONCLUSION

From the U.S. military's original navigational designs for its ballistic missile submarine force and its desire to protect national security communications in the event of an attack, the ideas that drove the development of GPS navigation and the Internet surpassed military constraints and exploded onto mass commercial markets in the 1990s.

Like their creations, scientists' worldviews eclipsed the narrow confines of their immediate tasks. In considering the pursuit of knowledge, many thoughtfully drew from moral codes, beliefs, and imaginations spurred by leisure activities. For instance, the growth of science fiction during this period fascinated many scientists, and led them to make real the science and technology of fictional worlds.