2

Why Build Computers?

The Military Role in Computer Research

> On the battlefield of the future, enemy forces will be located, tracked, and targeted almost instantaneously through the use of data links, computer assisted intelligence evaluation, and automated fire control. With first round kill probabilities approaching certainty, and with surveillance devices that can continually track the enemy, the need for large forces to fix the opposition physically will be less important. . . . [A]n improved communicative system . . . would permit commanders to be continually aware of the entire battlefield panorama down to squad and platoon level. . . . Today, machines and technology are permitting economy of manpower on the battlefield. . . . But the future offers even more possibilities for economy. I am confident the American people expect this country to take full advantage of its technology -- to welcome and applaud the developments that will replace wherever possible the man with the machine. . . . With cooperative effort, no more than 10 years should separate us from the automated battlefield.[1]
>
> -- General William Westmoreland, former Commander-in-Chief of U.S. forces in Vietnam, 1969

For two decades, from the early 1940s until the early 1960s, the armed forces of the United States were the single most important driver of digital computer development. Though most of the research work took place at universities and in commercial firms, military research organizations such as the Office of Naval Research, the Communications Security Group (known by its code name OP-20-G), and the Air Comptroller's Office paid for it. Military users became the proving ground for initial concepts and prototype machines. As the commercial computer industry began to take shape, the armed forces and the defense industry served as the major marketplace. Most historical accounts recognize the *financial* importance of this backing in early work on computers. But few, to date, have grasped the deeper significance of this military involvement.

At the end of World War II, the electronic digital computer technology we take for granted today was still in its earliest infancy. It was expensive, failure-prone, and ill-understood. Digital computers were seen as calculators, useful primarily for accounting and advanced scientific research. An alternative

---

[1] General William Westmoreland, U.S. Army Chief of Staff, "Address to the Association of the U.S. Army." Reprinted in Paul Dickson, *The Electronic Battlefield* (Bloomington, IN: Indiana University Press, 1976), 215–223.

technology, analog computing, was relatively cheap, reliable (if not terribly accurate), better developed, and far better supported by both industrial and academic institutions. For reasons we will explore below, analog computing was more easily adapted to the control applications that constituted the major uses of computers in battle. Only in retrospect does it appear obvious that command, control, and communications should be united within a single technological frame (to use Wiebe Bijker's term) centered around electronic digital computers.[2]

Why, then, did military agencies provide such lavish funding for digital computer research and development? What were their near-term goals and long-term visions, and how were these coupled to the grand strategy and political culture of the Cold War? How were those goals and visions shaped over time, as computers moved out of laboratories and into rapidly changing military systems?

I will argue that military support for computer research was rarely benign or disinterested, as many historians, taking at face value the public postures of funding agencies and the reports of project leaders, have assumed. Instead, practical military objectives guided technological development down particular channels, increased its speed, and helped shape the structure of the emerging computer industry. I will also argue, however, that the social relations between military agencies and civilian researchers were by no means one-sided. More often than not it was civilians, not military planners, who pushed the application of computers to military problems. Together, in the context of the Cold War, they enrolled computers as supports for a far-reaching discourse of centralized command and control -- as an enabling, infrastructural technology for the closed-world political vision.

The Background: Computers in World War II

During World War II, virtually all computer research (like most scientific research and development) was funded directly by the War Department as part of the war effort. But there are particularly intimate links between early digital computer research, key military needs, and the political fortunes of science and engineering after the war. These connections had their beginnings in problems of ballistics.

One of the Allies' most pressing problems in World War II was the feeble accuracy of antiaircraft guns. Airplanes had evolved enormously since World

---

[2] See Wiebe E. Bijker, "The Social Construction of Bakelite: Toward a Theory of Invention," in Bijker, Hughes, and Pinch, *The Social Construction of Technology*, 159–187.

War I, gaining speed and maneuverability. Defense from devastating bombing raids depended largely on ground-based antiaircraft weapons. But judging how far ahead of the fast-moving, rapidly turning planes to aim their guns was a task beyond the skills of most gunners. Vast amounts of ammunition were expended to bring down a distressingly small number of enemy bombers. The German V-I "buzz bombs" that attacked London in 1944 made a solution even more urgent. The problem was solved by fitting the guns with "servomechanisms" -- which combine a kind of mechanical or electro-mechanical analog computer with a control mechanism -- able to calculate the plane's probable future position.[3]

Building these devices, called "gun directors," required trajectory tables in which relations between variables such as the caliber of the gun, the size of its shell, and the character of its fuse were calculated out. Ballistics calculations of this sort have a long history in warfare, dating almost to the invention of artillery. Galileo, for example, invented and marketed a simple calculating aid called a "gunner's compass" that allowed artillerymen to measure the angle of a gun and compute, on an ad hoc basis, the amount of powder necessary to fire a cannonball a given distance.[4] As artillery pieces became increasingly powerful and complex, precalculated ballistics tables became the norm. The computation of these tables grew into a minor military industry. During World War I, young mathematicians such as Norbert Wiener and Oswald Veblen worked on these problems at the Army's Aberdeen Proving Ground. Such mathematicians were called "computers."[5]

In World War II, with its constant and rapid advances in gunnery, Aberdeen's work became a major bottleneck in fielding new artillery and

---

[3] *Mechanical* systems are classical Aristotelian machines (e.g., car engines) that perform work using the physical movement of levers, gears, wheels, etc. *Electro-mechanical* systems are machines powered by electric motors or electromagnets (e.g., vacuum cleaners), but part or all of whose function is still performed through the physical movement of parts. *Electronic* systems, by contrast, contain few or no moving parts. They consist entirely of electrical circuitry and perform their work through transformations of electric current (e.g., televisions or stereo systems).

The distinction between *digital* and *analog* methods corresponds closely to the more intuitive difference between *counting* and *measuring*. Digital calculation uses *discrete* states, such as the ratchet-like detents of clockwork gears (mechanical), the on-off states of relays (electro-mechanical switches), or the positive or negative electrical states of transistors (electronic), to represent discrete numerical values (1, 2, 3, etc.). These values can then be added, subtracted, and multiplied, essentially by a process of counting. Analog calculation, by contrast, employs *continuously variable* states, such as the ratio between the moving parts of a slide rule (mechanical), the speed of a motor's rotation (electro-mechanical), or the voltage of a circuit (electronic), to represent continuously variable numerical quantities (e.g., *any* value between 0 and 10). These quantities can then be physically combined to represent addition, subtraction, and multiplication, for example as someone might measure the perimeter of a room by cutting pieces of string to the length of each wall and then tying them together.

[4] Michael R. Williams, *A History of Computing Technology* (Englewood Cliffs, NJ: Prentice-Hall, 1985), 78–83.

[5] Pesi R. Masani, *Norbert Wiener, 1894–1964* (Boston: Birkhäuser, 1990), 68.

antiaircraft systems. Both Wiener and Veblen -- by then distinguished professors at MIT and Princeton respectively -- once again made contributions. Wiener worked on the antiaircraft gunnery problem at its most general level. His wartime studies culminated in the theory of cybernetics (a major precursor of cognitive psychology). Veblen returned to Aberdeen's ballistics work as head of the scientific staff of the Ballistics Research Laboratory (BRL). Just as in World War I, Veblen's group employed hundreds of people, this time mostly women, to compute tables by hand using desk calculators. These women, too, were called "computers." Only later, and gradually, was the name transferred to the machines.[6]

But alongside them Aberdeen also employed the largest analog calculator of the 1930s: the differential analyzer, invented by MIT electrical engineer Vannevar Bush.

Vannevar Bush: Creating an Infrastructure for Scientific Research

Bush invented the differential analyzer at MIT in 1930 to assist in the solution of equations associated with large electric power networks. The machine used a system of rotating disks, rods, and gears powered by electric motors to solve complex differential equations (hence its name). The BRL immediately sought to copy the device, with improvements, completing its own machine in 1935 at Aberdeen. At the same time, another copy was constructed at the University of Pennsylvania's Moore School of Engineering in Philadelphia, this one to be used for general-purpose engineering calculation. The Moore School's 1930s collaboration with the BRL, each building a differential analyzer under Bush's supervision, was to prove extremely important. During World War II, the two institutions would collaborate again to build the ENIAC, America's first full-scale electronic digital computer.

Bush was perhaps the single most important figure in American science during World War II, not because of his considerable scientific contributions but because of his administrative leadership. As war approached, Bush and some of his distinguished colleagues had used their influence to start organizing the scientific community for the coming effort. After convincing President

---

[6] The transfer of the name "computer" to the machine was by no means immediate. The *Reader's Guide to Periodical Literature* does not list "computer" as a heading until 1957. Most news articles of the 1945–1955 period place the word, if they use it at all, in scare quotes. See Paul E. Ceruzzi, "When Computers Were Human," *Annals of the History of Computing*, Vol. 13, No. 3 (1991), 237–244; Henry S. Tropp et al., "A Perspective on SAGE: Discussion," *Annals of the History of Computing*, Vol. 5, No. 4 (1983), 375–398; Jean J. Bartik and Frances E. Holberton, interviewed by Richard R. Mertz, 5/28/70, Smithsonian Computer Oral History, AC NMAH #196 (Archive Center, National Museum of American History, Washington, D.C.).

Roosevelt that close ties between the government and scientists would be critical to this war, they established the National Defense Research Committee (NDRC) in 1940, with Bush serving as chair. When the agency's mandate to conduct research but not development on weapons systems proved too restrictive, Bush created and took direction of an even larger organization, the development-oriented Office of Scientific Research and Development (OSRD), which subsumed the NDRC.[7] The OSRD coordinated and supervised many of the huge science and engineering efforts mobilized for World War II. By 1945 its annual spending exceeded $100 million; the prewar *total* for military R&D had been about $23 million.[8]

Academic and industrial collaboration with the military under the OSRD was critically important in World War II. Research on radio, radar, the atomic bomb, submarines, aircraft, and computers all moved swiftly under its leadership. Bush's original plans called for a decentralized research system in which academic and industrial scientists would remain in their home laboratories and collaborate at a distance. As the research effort expanded, however, this approach became increasingly unwieldy, and the OSRD moved toward a system of large central laboratories.

Contracts with universities varied, but under most of them the university provided laboratory space, management, and some of the scientific personnel for large, multidisciplinary efforts. The Radio Research Laboratory at Harvard employed six hundred people, more of them from California institutions than from Harvard itself. MIT's Radiation Laboratory, the largest of the university research programs, ultimately employed about four thousand people from sixty-nine different academic institutions.[9] Academic scientists went to work for industrial and military research groups, industrial scientists assisted universities, and the military's weapons and logistics experts and liaison officers were frequent visitors to every laboratory. The war effort thus brought about the most radical disciplinary mixing, administrative centralization, and social reorganization of science and engineering ever attempted in the United States.

It would be almost impossible to overstate the long-term effects of this enormous undertaking on American science and engineering. The vast interdisciplinary effort profoundly restructured scientific research communities. It solidified the trend to science-based industry -- already entrenched in the

---

[7] On the NDRC and OSRD, see Daniel Kevles, *The Physicists* (New York: Alfred A. Knopf, 1971); David Dickson, *The New Politics of Science* (New York: Pantheon, 1984); and Bruce L. R. Smith, *American Science Policy since World War II* (Washington DC: Brookings Institution, 1991).

[8] Paul Forman, "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940–1960," *Historical Studies in the Physical and Biological Sciences*, Vol. 18, No. 1 (1987), 152.

[9] James Phinney Baxter, *Scientists Against Time* (Boston: Little, Brown, 1946), 21. On the Radiation Laboratory see also Karl L. Wildes and Nilo A. Lindgren, *A Century of Electrical Engineering and Computer Science at MIT, 1882–1982* (Cambridge, MA: MIT Press, 1985).

interwar years -- but it added the new ingredient of massive government funding and military direction. MIT, for example, "emerged from the war with a staff twice as large as it had had before the war, a budget (in current dollars) four times as large, and a *research* budget ten times as large -- 85 percent from the military services and their nuclear weaponeer, the AEC."[10] Eisenhower famously named this new form the "military-industrial complex," but the nexus of institutions is better captured by the concept of the "iron triangle" of self-perpetuating academic, industrial, and military collaboration.[11]

Almost as important as the institutional restructuring was the creation of an unprecedented *experience* of community among scientists and engineers. Boundaries between scientific and engineering disciplines were routinely transgressed in the wartime labs, and scientists found the chance to apply their abilities to create useful devices profoundly exciting. For example, their work on the Manhattan Project bound the atomic physicists together in an intellectual and social brotherhood whose influence continued to be felt into the 1980s. Radiation Laboratory veterans protested vigorously when the lab was to be abruptly shut down in December 1945 as part of postwar demobilization; they could not believe the government would discontinue support for such a patently valuable source of scientific ideas and technical innovations. Their outcry soon provoked MIT, supported by the Office of Naval Research (ONR), to locate a successor to the Rad Lab in its existing Research Laboratory of Electronics.[12] Connections formed during the war became the basis, as we will see over and over again, for enduring relationships between individuals, institutions, and intellectual areas.

Despite his vast administrative responsibilities, Bush continued to work on computers early in the war. He had, in fact, begun thinking in 1937–38 about a possible electronic calculator based on vacuum tubes, a device he called the Rapid Arithmetical Machine. Memoranda were written and a research assistant was engaged. But Bush dropped the project as war brought more urgent needs. His assistant, Wilcox Overbeck, continued design work on the machine, but he too was finally forced to give up the project when he was drafted in 1942. Most of Overbeck's work focused on tube design, since Bush was concerned that the high failure rates of existing vacuum tubes would render the Rapid Arithmetical Machine too unreliable for practical use. Possibly because of this experience, Bush

---

[10] Forman, "Behind Quantum Electronics," 156–157.

[11] See David Noble, *America By Design: Science, Technology, and the Rise of Corporate Capitalism* (Oxford: Oxford University Press, 1977), as well as Dickson, *New Politics of Science*, and Merritt Roe Smith, ed., *Military Enterprise and Technological Change* (Cambridge, MA: MIT Press, 1985). The phrase "iron triangle" is from Gordon Adams, *The Politics of Defense Contracting: The Iron Triangle* (New Brunswick, NJ: Transaction Books, 1982).

[12] Wildes and Lindgren, A *Century of Electrical Engineering and Computer Science at MIT*, 289 and passim.

opposed fully electronic computer designs until well after the end of World War II.[13]

Bush did, however, perfect a more powerful version of the differential analyzer, known as the Rockefeller Differential Analyzer (after its funding source) at MIT in 1942. This device could be programmed with punched paper tape and had some electronic components. Though committed to analog equipment and skeptical of electronics, he kept abreast of the Moore School's ENIAC project, and the universe of new possibilities opened up by computers intrigued him.[14]

Thus it so happened that the figure most central to World War II science was also the inventor of the prewar period's most important computer technology. Bush's laboratory at MIT had established a tradition of analog computation and control engineering -- not, at the time, separate disciplines -- at the nation's most prestigious engineering school. This tradition, as we will see, weighed against the postwar push to build digital machines. Simultaneously, though, the national science policies Bush helped create had the opposite effect. The virtually unlimited funding and interdisciplinary opportunities they provided encouraged new ideas and new collaborations, even large and expensive ones whose success was far from certain. Such a project was the Moore School's Electronic Numerical Integrator and Calculator (ENIAC), the first American electronic digital computer.

The ENIAC Project

Even with the help of Bush's differential analyzer, compiling ballistics tables for antiaircraft weapons and artillery involved tedious calculation. Tables had to be produced for every possible combination of gun, shell, and fuse; similar tables were needed for the (analog) computing bombsight and for artillery pieces. Even with mechanical aids, human "computers" made frequent mistakes, necessitating time-consuming error-checking routines. The BRL eventually commandeered the Moore School's differential analyzer as well. Still, with two of these machines, the laboratory fell further and further behind in its work.

---

[13] Ibid., 229. J.C.R. Licklider speculated that Bush's dislike of digital machines stemmed from an argument with Norbert Wiener over whether binary arithmetic was the best base to use. See John A. N. Lee and Robert Rosin, "The Project MAC Interviews," *IEEE Annals of the History of Computing*, Vol. 14, No. 2 (1992), 22.

[14] See, for example, Bush's prescient article on the "memex," a kind of hypertext technology, in "As We May Think," *Atlantic Monthly* 176, 1945. Reprinted in Zenon Pylyshyn, ed., *Perspectives on the Computer Revolution* (Englewood Cliffs: Prentice-Hall, 1970), 47–59.

"The automation of this process was . . . the *raison d'être* for the first electronic digital computer," wrote Herman Goldstine, co-director of the ENIAC project. The best analog computers, even those built during the war, were only "about 50 times faster than a human with a desk machine. None of these [analog devices were] sufficient for Aberdeen's needs since a typical firing table required perhaps 2,000–4,000 trajectories. . . . The differential analyzer required perhaps 750 hours -- 30 days -- to do the trajectory calculations for a table."[15] (To be precise, however, these speed limitations were due not to the differential analyzer's *analog* characteristics, but to its electro-mechanical nature. Electronic equipment, performing many functions at the speed of light, could be expected to provide vast improvements. As Bush's RDA had demonstrated, electronic components could be used for analog as well as digital calculation. Thus nothing in Aberdeen's situation dictated a *digital* solution to the computation bottleneck.)

The Moore School started research on new ways of automating the ballistics calculations, under direct supervision of the BRL and the Office of the Chief of Ordnance. In 1943 Moore School engineers John Mauchly and J. Presper Eckert proposed the ENIAC project. They based its digital design in part on circuitry developed in the late 1930s by John Atanasoff and Clifford Berry of the Iowa State College. (Atanasoff and Berry, however, never pursued their designs beyond a small-scale prototype calculator, conceiving it, as did most engineers of their day, more as a curiosity of long-term potential than as an immediate alternative to existing calculator technology.)[16] The BRL, at this point desperate for new assistance, approved the project over the objections of Bush, who thought the electronic digital design infeasible.

The ENIAC represented an electrical engineering project of a completely unprecedented scale. The machine was about 100 times larger than any other existing electronic device, yet to be useful it would need to be at least as reliable as far smaller machines. Calculations revealed that because of its complexity, the ENIAC would have to operate with only one chance in 10^{14} of a circuit failure in order to function continuously for just twelve hours. Based on these estimates, some of ENIAC's designers predicted that it would operate only about 50 percent of the time, presenting a colossal maintenance problem, not to mention a challenge to operational effectiveness.[17]

---

[15] Herman Goldstine, *The Computer from Pascal to von Neumann* (Princeton, NJ: Princeton University Press, 1972), 135–136. As noted in chapter 1, the British Colossus, not the ENIAC, was actually the first electronic digital computer. Because of British secrecy, Goldstine may not have known this when he wrote the cited lines in 1972.

[16] Williams, *History of Computing Technology*; Stan Augarten, *Bit by Bit: An Illustrated History of Computers* (New York: Ticknor & Fields, 1984); 119–120.

[17] Williams, *History of Computing Technology*, 275. The estimate of part failure probability is due to Herman Goldstine.

When completed in 1945, the ENIAC filled a large room at the Moore School with equipment containing 18,000 vacuum tubes, 1500 relays, 70,000 resistors, and 10,000 capacitors. The machine consumed 140 kilowatts of power and required internal forced-air cooling systems to keep from catching fire. The gloomy forecasts of tube failure turned out to be correct, in one sense: when the machine was turned on and off on a daily basis, a number of tubes would burn out almost every day, leaving it nonfunctional about 50 percent of the time, as predicted. Most failures, however, occurred during the warm-up and cool-down periods. By the simple (if expensive) expedient of never turning the machine off, the engineers dropped the ENIAC's tube failures to the more acceptable rate of one tube every two days.[18]

The great mathematician John von Neumann became involved with the ENIAC project in 1944, after a chance encounter with Herman Goldstine on a train platform. By the end of the war, with Eckert, Mauchly, and others, von Neumann had planned an improved computer, the EDVAC. The EDVAC was the first machine to incorporate an internal stored program, making it the first true computer in the modern sense.[19] (The ENIAC was programmed externally, using switches and plugboards.) The plan for the EDVAC's logical design served as a model for nearly all future computer control structures -- often called "von Neumann architectures" -- until the 1980s.[20]

Initially budgeted at $150 thousand, the ENIAC finally cost nearly half a million dollars. Without the vast research funding and the atmosphere of desperation associated with the war, it probably would have been years, perhaps decades, before private industry attempted such a project. The ENIAC became, like radar and the bomb, an icon of the miracle of government-supported "big science."

---

[18] Ibid., 285.

[19] In contemporary parlance the word "computer" refers to electronic digital machines with a memory and one or more central processing units. In addition, to qualify as a computer a device must be capable of (a) executing conditional branching (i.e., carrying out different sets of instructions depending upon the results of its own prior calculations) and (b) storing these instructions (programs) internally. Babbage's Analytical Engine had most of these features but would have stored its programs externally on punched wooden cards. Somewhat like the Analytical Engine, the EDVAC was only partially completed; thus it represents the first true computer *design* but not the first actually operating computer. Instead, the British Manchester University Mark I achieved that honor in 1948. See Williams, *History of Computing Technology*, 325; Augarten, *Bit by Bit*, 149.

[20] Goldstine distributed this plan, under von Neumann's name but unbeknownst to him, as the famous and widely read "Draft Report on the EDVAC." Because von Neumann's name was on its cover, the misunderstanding arose that he was the report's sole author. But many of the Draft Report's key ideas actually originated with Eckert, Mauchly, and other members of the ENIAC design team. Because of this misunderstanding, which later escalated into a lawsuit, and the fame he acquired for other reasons, von Neumann has received more credit for originating computer design than he probably deserved. See Augarten, *Bit by Bit*, 136ff. The most essential feature of the so-called von Neumann architecture is serial (one-by-one) processing of the instruction stream.

The ENIAC was not completed until the fall of 1945, after the war had ended. The ballistics tables ENIAC was built to compute no longer required urgent attention. But the ENIAC was a military machine, and so it was immediately turned to the military ends of the rapidly emerging Cold War. The first problem programmed on the machine was a mathematical model of a hydrogen bomb from the Los Alamos atomic weapons laboratories. The ENIAC, unable to store programs or retain more than twenty ten-digit numbers in its tiny memory, required several weeks in November 1945 to run the program in a series of stages. The program involved thousands of steps, each individually entered into the machine via its plugboards and switches, while the data for the problem occupied one million punch cards. The program's results exposed several problems in the proposed H-bomb design. The director of Los Alamos expressed his thanks to the Moore School in March 1946, writing that "the complexity of these problems is so great that it would have been impossible to arrive at any solution without the aid of ENIAC."[21]

This event was symbolic of a major and portentous change. The wartime alliance of academic and industrial science with the military had begun as a temporary association for a limited purpose: winning a war against aggressors. Now it was crystallizing into a permanent union.

At the formal dedication ceremony on February 15, 1946, just before pressing a button that set the ENIAC to work on a new set of hydrogen bomb equations, Major General Gladeon Barnes spoke of "man's endless search for scientific truth." In turning on the ENIAC, he said he was "formally dedicating the machine to a career of scientific usefulness."[22] Barnes, like many others in the aftermath of World War II, failed to find irony in the situation: that the "scientific truth" the ENIAC began to calculate was the basis for ultimate weapons of destruction.

Directing Research in the Postwar Era

As the postwar Truman administration began to tighten the strings of the virtually unlimited wartime purse, expectations in many quarters were that, like

---

[21] Augarten, *Bit by Bit*, 130–131, citing Nancy Stern, *From ENIAC to UNIVAC* (Boston: Digital Press, 1981)**.** Whether the ENIAC was actually able to solve this first problem is a matter of debate among historians. Kenneth Flamm, citing an interview with Stanley Frankel (Smithsonian Institution Computer Oral History Project, October 5, 1972, conducted by Robina Mapstone), holds that it failed and that the calculations were actually carried out later at Eckert and Mauchly's UNIVAC factory in Philadelphia. See Kenneth Flamm, *Targeting the Computer: Government Support and International Competition* (Washington, DC: Brookings Institution, 1987), 79.

[22] Barnes, cited in Goldstine, *The Computer from Pascal to von Neumann*, 229.

the armed forces, the enormous scientific and engineering network assembled for the war effort would be demobilized and thrown on its own resources.

For a number of reasons, the looming fiscal constraints never materialized. Postwar federal expenditures for R&D remained far higher than before the war, with most of the money channeled through the armed forces.

> In [fiscal year] 1938 the total U.S. budget for military research and development was $23 million and represented only 30 percent of all Federal R&D; in fiscal 1945 the OSRD alone spent more than $100 million, the Army and Navy together more than $700 million, and the Manhattan Project more than $800 million. . . . In the immediate postwar years total military expenditure slumped to a mere seven times its prewar constant-dollar level, while constant-dollar military R&D expenditure held at a full 30 times its prewar level, and comprised about 90 percent of all federal R&D. In the early 1950s total military expenditure soared again, reaching 20 times its prewar constant-dollar level, while military R&D reattained, and before the end of the decade much surpassed, its World War II high.[23]

Industrial R&D expenditures soared as well. By the late 1940s the total amount of industrial R&D roughly equaled that sponsored by the federal government, but as figure 2.1 shows, a decade later government R&D spending was nearly double that of industry.

This trend, and the politics it reflected, resulted from the three concurrent developments in postwar America politics. First, in the rapid transition from World War II to the Cold War, the war's key events served as anchoring icons for postwar policies. Wartime institutions became blueprints for their postwar counterparts. Second, the emerging politico-military paradox of a peacetime Cold War generated a perceived need for new technology, justifying vast military investments in research. Finally, fierce public debates about postwar federal support for science and technology had ended in stalemate. Plans for a National Science Foundation suffered long delays, and military agencies were left to fill the resulting vacuum. Let us explore each of these developments in turn.

Transference and Apocalypse

---

[23] Forman, "Behind Quantum Electronics," 152.

World War II was “the good war,” a war not only against greedy, power-hungry aggressors but against an inhumane, antidemocratic ideology. This nearly universal sentiment was vindicated and vastly amplified by postwar revelations of the horrors of the Nazi concentration camps.

Soviet maneuverings in Eastern Europe, as well as the openly expansionist Soviet ideology, provided grounds for the transition into a Cold War. Stalin was rapidly equated with Hitler. The closed nature of Soviet society added a sinister force to mounting rumors of purges and gulag atrocities. In the eyes of many Americans, communism replaced fascism as an absolute enemy. It was seen (and saw itself) not just as one human order among others, but as an ultimate alternative system, implacably opposed to Western societies in virtually every arena: military, political, ideological, religious, cultural, economic. The absoluteness of the opposition allowed the sense of an epic, quasi-Biblical struggle that surrounded the fight against Nazism and fascism not only to survive but to thrive.

This transference of attitudes from World War II to the Cold War included a sense of a global, all-encompassing, *apocalyptic* conflict. In the 1940s and 1950s the partitioning of Europe, revolutionary upheavals across the postcolonial world, and the contest for political and ideological alliances throughout Europe, Asia, and the Middle East encouraged American perceptions that the world’s future balanced on a knife edge between the United States and the USSR. Truman’s declaration of worldwide American military support for “free peoples who are resisting attempted subjugation by armed minorities or by outside pressures” codified the continuation of global conflict on a permanent basis and elevated it to the level of a universal struggle between good and evil, light and darkness, freedom and slavery.[24]

The only combatant nation to emerge from the war intact, the United States had simultaneously left behind the economic depression and the political isolationism of the 1930s. The magnitude of this change cannot be overemphasized, since we have become used to a very different world.[25] The United States was a world *industrial* power before the Great Depression, but with a few brief exceptions had played only a minor role in world political and military affairs during a period when the European colonial empires still ruled the globe. As late as 1939, the U.S. army numbered only 185,000 men, with an annual budget under $500 million. America maintained no military alliances

[24] Harry S Truman, cited in Ambrose, *Rise to Globalism*, 86.

[25] By the Cold War’s end in 1989, peacetime military budgets routinely reached levels in excess of $300 billion. America had 1.5 million men and women in uniform, defense alliances with 50 nations, and military bases in 117 countries.

with any foreign country.[26] Six years later, at the end of World War II, the United States had over 12 million men under arms and a military budget swollen to 100 times its prewar size. In addition,

> the U.S. was producing 45 percent of the world's arms and nearly 50 percent of the world's goods. Two-thirds of all the ships afloat were American built. . . . The conclusion of the war . . . found the U.S. either occupying, controlling, or exerting strong influence in four of the five major industrial areas of the world -- Western Europe, Great Britain, Japan, and the U.S. itself. Only the Soviet Union operated outside the American orbit. . . . The U.S. was the only nation in the world with capital resources available to solve the problems of postwar reconstruction.[27]

The old colonial empires were bankrupt and on the verge of disintegration, the imperial pretensions of Japan had been smashed, and the Soviet Union, though still powerful, had suffered staggering losses. Postwar public sentiment for a return to the isolationism of the 1930s was strong, as was fear of renewed economic depression. The Truman administration initially tended to honor these worries with its heavy focus on a balanced budget and a rapid military demobilization. But the transference of World War II's apocalyptic struggles into the postwar world, the sense of America's awesome power, the fear of future nuclear war, and the need to re-establish war-torn nations as markets for American goods -- to stave off the feared depression -- combined to render isolationism untenable. The postwar geopolitical situation thus catapulted the United States into a sudden and unaccustomed role as world leader.

America's leaders in the postwar world had been weaned on the isolationist worldview. Except for a brief period after World War I, the United States had never before played a controlling role in world affairs. Thus the war itself provided the only immediately available models for action. Key events of World War II became basic icons in the organization of American foreign policy and military strategy:

- The 1938 Munich accords, in which Great Britain and France handed over parts of Czechoslovakia to Hitler in a futile attempt to stave off war, symbolized the danger of appeasement.

---

[26] Ambrose, *Rise to Globalism*, xiii.
[27] Ibid., 30, 53.

- The Maginot Line -- a chain of massive fortresses along the French-German border that the Germans had avoided by the simple maneuver of invading through Belgium -- represented the foolhardiness of a defensive grand strategy.

- Pearl Harbor, where unopposed Japanese aircraft destroyed or disabled a significant portion of the U.S. Pacific fleet, signified the perpetual danger of surprise attack.

- Radar (and MIT's Radiation Laboratory, which led wartime radar research) and the Manhattan Project came to represent the power of organized science to overcome military odds with ingenuity.

- The atomic bomb itself, credited with the rapid end to the war in the Pacific, became the enigmatic symbol of both invincible power and global holocaust.

The unfolding political crises of the Cold War *were invariably interpreted in these terms*.[28] For example, the Berlin blockade was perceived as another potential Munich, calling for a hard-line response rather than a negotiation. Truman interpreted Korea through the lens of World War II: "Communism was acting in Korea just as Hitler, Mussolini and the Japanese had acted. . . . I felt certain that if South Korea was allowed to fall, Communist leaders would be emboldened to override nations closer to our own shores."[29] Critics of the 1950s characterized continental air defense as a Maginot Line strategy for starry-eyed technological optimists. U.S. forward basing of nuclear weapons, in positions vulnerable to surprise air attack, was likened to the risk of another Pearl Harbor.[30] The Manhattan Project was invoked endlessly to rally support for major R&D projects such as the space program. Finally, the growing nuclear arsenal was a reminder of Hiroshima, both horror and symbol of ultimate power, and it was simply assumed (for a while) that no nation would be willing to stand up to a weapon of such destructive force.[31]

---

[28] Rystad has named this interpretation the "Munich paradigm." See Göran Rystad, *Prisoners of the Past?* (Lund, Sweden: CWK Gleerup, 1982), 33 and passim.

[29] Harry S Truman, *Memoirs: Years of Trial and Hope*, Vol. 2 (Garden City, NJ: Doubleday, 1956), 332–333.

[30] Herbert York, Los Alamos physicist and Eisenhower advisor, noted that "because of Pearl Harbor you didn't have to discuss the notion of surprise attack. It was in your bones that the Russians are perfidious, that surprise attack is the way wars always start, and that appeasement doesn't work." Cited in Gregg Herken, *Counsels of War* (New York: Knopf, 1983), 125.

[31] Atomic bombs, of course, were only one in a long line of weapons Americans (and others) believed would make war too terrible to fight. See Franklin, *War Stars*.

Thus in many respects the Cold War was not a new conflict with communism but the continuation of World War II, the transference of that mythic, apocalyptic struggle onto a different enemy.[32]

American Antimilitarism and a High-Technology Strategy

The authors of the U.S. Constitution feared professional armies as dangerous concentrations of unaccountable state power. They saw the career officer corps, which in European armies maintained the hereditary linkage between royalty, gentry, and control of the armed forces, as a linchpin of aristocracy. In addition military social structure, with its strict hierarchy and its authoritarian ethic, seemed the antithesis of a participatory democracy.[33]

But having won their independence in a revolutionary war, the founders naturally also understood the importance of military power in international politics. The constitutional provision for a citizen army linked the right to participate in government with the responsibility to protect it by force of arms. Every citizen was a potential soldier, but every soldier was also a citizen; thus, in principle, loyalty to military institutions was subordinated to loyalty to state and civil society. In practice, until World War II, this also meant that armed forces were mustered only for war and were greatly reduced once war ended. American political discourse still reflects this ambivalence toward military forces and the conflictual relationship between democratic ideals and military principles of authority.[34]

American antimilitarism, then, is not at all the same thing as pacifism, or principled objection to armed force itself. Instead, antimilitarism is an instance of what the political scientist Samuel Huntington calls the "anti-power ethic" in American society, the enormous value this society has always placed on political limits to power, hierarchy, and authority.[35]

In the postwar years a number of factors contributed to a changed perception of the need for a powerful armed force in peacetime. The absolute

---

[32] Baritz, *Backfire*, makes a compelling case for a similar argument.

[33] On military social and political relations in the pre-revolutionary era, see Maury D. Feld, *The Structure of Violence: Armed Forces as Social Systems* (Beverly Hills: Sage, 1977). The tension between the authoritarian military ethic and democratic principles is the focus of a number of novels and films, such as Charles Nordhoff's *Mutiny on the Bounty* (Boston: Little, Brown, 1932) and Rob Reiner's 1992 film *A Few Good Men,* based on Aaron Sorkin's play of the same title.

[34] I owe this point to Robert Meister.

[35] See Samuel Huntington, *American Politics: The Promise of Disharmony* (Cambridge: Belknap Press, 1981).

Allied victory supported a vast new confidence in the ability of military force to solve political problems. The occupation of Germany and Japan meant an ongoing American military presence on other continents. The relative insignificance of American suffering in the war produced an inflated sense of the ease of military victory -- the idea that the United States, at least, could buy a lot for a little with military power and new technology. Also, with America's full-blown emergence as a world economic power came new interests across the globe, interests that could conceivably require military defense. Finally, the rapid transition from World War II into the Cold War left little time for a retrenchment into prewar values: the apocalyptic conflict simply continued.

Furthermore, technological factors such as the bomb and the maturation of air warfare now made it possible to conceive of a major military role for the United States outside its traditional North American sphere of influence. Historically, ocean barriers had separated the United States from the other nations possessing the technological wherewithal to mount a serious military challenge. These were now breached. Airplanes and, later, guided missiles could pose threats at intercontinental range. In effect, the very concept of national borders was altered by these military technologies: the northern boundary of the United States, in terms of its defense perimeter, now lay at the limits of radar vision, which in the 1950s rapidly moved northward to the Arctic Circle.

Antimilitarism, because it required that the number of men under arms be minimized, also helped to focus strategic planning on technological alternatives. The Strategic Air Command came to dominate U.S. strategic planning because it controlled the technological means for intercontinental nuclear war. It was the primary threat America could wield against the Soviet Union, yet it required mainly money and equipment, not large numbers of troops. The Army's massive manpower seemed less impressive, less necessary, and more of a political liability in the face of the minimally manned or even automated weapons of the Air Force. As the Soviet Union acquired long-range bombers, nuclear weapons, and then ICBMs, the role of the Air Force and its technology in both defense and offense continued to expand.

The Cold War marked the first time in its history that America maintained a large standing army in peacetime. But its geographical situation of enormous distance from its enemies, combined with its antimilitarist ethic, ensured that the institutional form taken by a more vigorous American military presence would differ from the more traditional European and Soviet approaches of large numbers of men under arms. Instead of universal conscription, the United States chose the technological path of massive, ongoing automation and integration of humans with machines. First Truman and then Eisenhower, each balancing the contradictory goals of an expanding, activist global role and a contracting military budget, relied ever more heavily on nuclear weapons. By the end of the 1950s high technology -- smaller bombs with higher yields, tactical atomic warheads for battlefield use, bombers of increasingly long range, high-altitude spy planes, nuclear early warning systems, and rockets to launch spy satellites and ICBMs -- had became the very core of American global power.

Support for Research and Development

In his famous 1945 tract *Science: The Endless Frontier*, composed at President Roosevelt's request as a blueprint for postwar science and technology policy, Vannevar Bush called for a civilian-controlled National Research Foundation to preserve the government-industry-university relationship created during the war. In his plea for continuing government support, Bush cited the Secretaries of War and Navy to the effect that scientific progress had become not merely helpful but utterly essential to military security for the United States in the modern world:

> This war emphasizes three facts of supreme importance to national security: (1) Powerful new tactics of defense and offense are developed around new weapons created by scientific and engineering research; (2) the competitive time element in developing those weapons and tactics may be decisive; (3) war is increasingly total war, in which the armed services must be supplemented by active participation of every element of the civilian population.
>
> To insure continued preparedness along farsighted technical lines, the research scientists of the country must be called upon to continue in peacetime some substantial portion of those types of contribution to national security which they have made so effectively during the stress of the present war.[36]

Bush's MIT colleague Edward L. Bowles, Radiation Laboratory "ambassador" to government and the military, advocated an even tighter connection. Bowles wrote of the need to "systematically and deliberately couple"

[36] Secretaries of War and Navy, joint letter to the National Academy of Sciences, cited in Vannevar Bush, *Science: The Endless Frontier* (Washington: U.S. Government Printing Office, 1945), 12.

scientific and engineering schools and industrial organizations with the military forces “so as to form a continuing, working partnership.”[37]

Bush also argued that modern medicine and industry were also increasingly dependent on vigorous research efforts in basic science. The massive funding requirements of such research could not be met by the cash-poor academic community, while the industrial sector’s narrow and short-term goals would discourage it from making the necessary investment. Consequently the new foundation Bush proposed would have three divisions, one for natural sciences, one for medical research, and one for national defense.

Bush’s efforts were rebuffed, at first, by Truman’s veto of the bill establishing the NSF. The populist president blasted the bill, which in his view “would . . . vest the determination of vital national policies, the expenditure of large public funds, and the administration of important government functions in a group of individuals who would be essentially private citizens. The proposed National Science Foundation would be divorced from . . . control by the people.”[38]

With major research programs created during the war in jeopardy, the War Department moved into the breach, creating the Office of Naval Research in 1946. In a pattern repeated again and again during the Cold War, national security provided the consensual justification for federally funded research. The ONR, conceived as a temporary stopgap until the government created the NSF, became the major federal force in science in the immediate postwar years and remained important throughout the 1950s. Its mandate was extremely broad: to fund basic research (“*free* rather than directed research”), primarily of an unclassified nature.[39]

Yet the ONR’s funding was rarely, if ever, a purely altruistic activity.[40] The bill creating the office mentions the “paramount importance [of scientific research] as related to the maintenance of future naval power, and the preservation of national security”; the ONR’s Planning Division sought to maintain “listening posts” and contacts with cutting-edge scientific laboratories

---

[37] Bowles, cited in Wildes and Lindgren, *A Century of Electrical Engineering and Computer Science at MIT*, 203.

[38] Harry S Truman, cited in James L. Penick Jr. et al., *The Politics of American Science: 1939 to the Present*, revised ed. (Cambridge, MA: MIT Press, 1972), 20.

[39] The Vinson Bill creating the ONR, cited in ibid., 22.

[40] For a somewhat different view of the ONR, see Harvey Sapolsky, *Science and the Navy* (Princeton, NJ: Princeton University Press, 1990). Among the best, and certainly to date the most detailed, discussions of the mixed motives of military support for postwar academic research is Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993).

for the Navy's possible use.[41] Lawmakers were well aware that the ONR represented a giant step down the road to a permanent federal presence in science and engineering research and a precedent for military influence. House Committee on Naval Affairs Chairman Carl Vinson opposed the continuing executive "use of war powers in peacetime," forcing the Navy to go to Congress for authorization.[42]

By 1948 the ONR was funding 40 percent of *all* basic research in the United States; by 1950 the agency had let more than 1,200 separate research contracts involving some 200 universities. About half of all doctoral students in the physical sciences received ONR support.[43] ONR money proved especially significant for the burgeoning field of computer design. It funded a number of major digital computer projects, such as MIT's Whirlwind, Raytheon's Hurricane, and Harvard's Mark III.[44] The NSF, finally chartered in 1950 after protracted negotiations, did not become a significant funding source for computer science until the 1960s (in part because computer science did not become an organized academic discipline until then). Even after 1967, the only period for which reliable statistics are available, the NSF's share of total federal funding for computer science hovered consistently around the 20 percent mark, while DoD obligations ranged between 50 and 70 percent, or 60 to 80 percent if military-related agencies such as the Department of Energy (responsible for atomic weapons research) and NASA (whose rockets lifted military surveillance satellites and whose research contributed to ballistic missile development) are included.[45]

The Military Role in Postwar Computer Research

[41] The Vinson Bill and the ONR Planning Division, cited in Penick et al., *The Politics of American Science*, 22–23.

[42] Vinson, quoted in Kent C. Redmond and Thomas M. Smith, *Project Whirlwind* (Boston: Digital Press, 1980), 105.

[43] Dickson, *New Politics of Science*, 118–119.

[44] See Mina Rees, "The Computing Program of the Office of Naval Research, 1946–1953," *Annals of the History of Computing*, Vol. 4, No. 2 (1982), 103–113.

[45] The figure of 20 percent for NSF support is generous, since the budget category used includes both mathematics and computer science research. On the DOE and NASA as auxiliary military agencies, see Flamm, *Targeting the Computer*, 46 and passim. My discussion in this chapter relies heavily on Flamm's published account; on some points I am indebted to him for personal communications as well. On NASA's role as a civilian cover for military research and the U.S. geostrategic aim of establishing international rights of satellite overflight (the "open skies" policy) in order to obtain intelligence about Soviet military activities, see Walter A. McDougall, *...the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985).

With the war's end, some corporate funding became available for computer research. A few of the wartime computer pioneers, such as ENIAC engineers Mauchly and Eckert, raised commercial banners. The company they formed developed the BINAC, the first American stored-program electronic computer, and then the UNIVAC, the first American commercial computer.[46]

But military agencies continued, in one way or another, to provide the majority of support. The Army (via the Census Bureau) and Air Force (via the Northrop Corporation's Snark missile project) were Eckert and Mauchly's major supporters. Bell Laboratories, the largest independent electronics research laboratory in the country, saw the percentage of its peacetime budget allocated to military projects swell from zero (prewar) to upwards of 10 percent as it continued work on the Nike missile and other systems, many of them involving analog computers.[47] Many university-based computer researchers continued under ONR sponsorship. Others became involved in a private company, Engineering Research Associates (ERA), which developed cryptological computers for its major customer, the Navy, as well as later commercial machines based on its classified work. (When ERA's ATLAS became operational, in 1950, it was the second electronic stored-program computer in the United States.)[48]

With military and Atomic Energy Commission support, John von Neumann began his own computer project at the Institute for Advanced Study (IAS). The so-called IAS machine, completed in 1952, became one of the most influential computers of the immediate postwar period. Several copies were built at defense research installations, including the Rand Corporation and the Los Alamos, Oak Ridge, and Argonne National Laboratories.[49]

How much military money went to postwar computer development? Because budgets did not yet contain categories for computing, an exact accounting is nearly impossible. Kenneth Flamm has nevertheless managed to calculate rough comparative figures for the scale of corporate and military support.[50] Flamm estimates that in 1950 the federal government provided between $15 and $20 million (current) per year, while industry contributed less than $5 million --

---

[47] M. D. Fagen, ed., *A History of Engineering and Science in the Bell System* (Murray Hill, NJ: Bell Telephone Laboratories, 1978), 11.

[48] Erwin Tomash and Arnold A. Cohen, "The Birth of an ERA: Engineering Research Associates, Inc., 1946–1955," *Annals of the History of Computing*, Vol. 1, No. 2 (1979), 83–97.

[49] Julian Bigelow, "Computer Development at the Institute for Advanced Study," in N. Metropolis, J. Howlett, and Gian-Carlo Rota, eds., *A History of Computing in the Twentieth Century* (New York: Academic Press, 1980), 291–310.

[50] Accounting for research and development costs is inherently problematic, for example because of the sometimes fine line between procurement and development expenditures. Defense Department accounting practices do not always offer a clearcut distinction between R&D and other budgets. See Flamm, *Targeting the Computer*, 94.

20 to 25 percent of the total. The vast bulk of federal research funds at that time came from military agencies.

In the early 1950s the company-funded share of R&D began to rise (to about $15 million by 1954), but between 1949 and 1959 the major corporations developing computer equipment -- IBM, General Electric, Bell Telephone, Sperry Rand, Raytheon, and RCA -- still received an average of 59 percent of their funding from the government (again, primarily from military sources). At Sperry Rand and Raytheon, the government share during this period approached 90 percent.[51] The first commercial production computer, Remington Rand's UNIVAC I, embodied the knowledge Eckert and Mauchly had gained from working on the military-funded ENIAC and later on their BINAC, which had been built as a guidance computer for Northrop Aircraft's Snark missile. Though much of the funding for Eckert and Mauchly's project was channeled through the Census Department (which purchased the first UNIVAC I), the funds were transferred to Census from the Army.[52]

Flamm also concludes that even when R&D support came primarily from company sources, it was often the expectation of military procurements that provided the incentive to invest. For instance, IBM's first production computer (the 701, also known as the "Defense Calculator"), first sold in 1953, was developed at IBM's expense, but only with letters of intent in hand from eighteen DoD customers.[53]

Consequences of Military Support

What sort of influence did this military support have on the development of computers? In chapters 3 and 4 we will explore this question in great detail with respect to the Whirlwind computer, the SAGE air defense system, the Rand Corporation, and the Vietnam War. Here, however, I will sketch some more general answers through a series of examples.

---

[51] Flamm, *Targeting the Computer*, 94–96.

[52] Nancy Stern, "The BINAC: A Case Study in the History of Technology," *Annals of the History of Computing*, Vol. 1, No. 1 (1979), 9–20; Stern, *From ENIAC to UNIVAC*. Shipped from Eckert and Mauchly's Philadelphia workshop to California, the BINAC failed to function after being reassembled. Northrop soon abandoned it in favor of analog computers.

[53] Flamm, *Targeting the Computer*, 64, 76. The outbreak of the Korean War caused IBM chairman Thomas J. Watson, Sr., to reactivate IBM's military products division, providing an opportunity for Thomas J. Watson, Jr., to initiate electronic computer development there. (See James Birkenstock, interviewed by Erwin Tomash and Roger Stuewer, 8/12/80. Charles Babbage Institute, University of Minnesota.)

First, military funding and purchases in the 1940s and 1950s enabled American computer research to proceed at a pace so ferocious as to sweep away competition from Great Britain, the only nation then in a position to become a serious rival. At the end of World War II the British possessed the world's only functioning, fully electronic digital computer (Turing's Colossus), and until the early 1950s its sophistication in computing at least equaled that of the United States. The Manchester University Mark I became, in June 1948, the world's first operating *stored-program* electronic digital computer (i.e., the first operating computer in the full modern sense of the term). The Cambridge University EDSAC, explicitly modeled on the EDVAC, preceded the latter into operation in June 1949, "the first stored-program electronic computer with any serious computational ability."[54] The firm of Ferranti Ltd. built the first successful commercial computer, also called the Mark I, and eventually sold eight of these machines, primarily to government agencies active in the British atomic weapons research program. The first Ferranti Mark I became operational in February 1951, preceding the Eckert/Mauchly UNIVAC by a few months.

With its financial resources limited by the severe demands of postwar reconstruction, the British government failed to pursue the field with the intensity of the United States. British researchers and producers were in general left to more ordinary commercial and technical resources. By the time large-scale commercial markets for computers developed in the early 1960s, British designs lagged behind American models. Unable to keep up, the fledgling British computer industry declined dramatically: though British firms totally dominated the British market in the 1950s, by 1965 more than half of computers operating in Britain were U.S.-made.[55]

Second, the military secrecy surrounding some of both British and American research impeded the spread of the new technology. Most academic researchers felt advances would come faster in an atmosphere of free exchange of ideas and results. They pressed to re-establish such a climate, and in many cases -- such as that of the IAS computer, whose technical reports and plans were widely disseminated -- they succeeded. But the wartime habits of secrecy died hard, and in the course of the Cold War tensions between military and commercial interests rose. In August 1947 Henry Knutson of the ONR's Special Devices Center informed Jay Forrester, director of the MIT Whirlwind computer project, that "the tendency is to upgrade the classification [of military-funded research projects] and that all computer contracts are now being reconsidered with the

[54] Williams, *History of Computing Technology*, 334.

[55] See Flamm, *Targeting the Computer*, 159 and passim and Flamm, *Creating the Computer: Government, Industry, and High Technology* (Washington, DC: Brookings Institution, 1988), 136–150.

possible view of making them confidential."[56] Much of the Whirlwind work was, in fact, classified. (Indeed, in the 1950s MIT spun off the Lincoln Laboratories from its university operations because of the huge volume of classified research on air defense, including computers.) In the late 1940s, Forrester sometimes had trouble recruiting researchers because so many people refused to work on military projects.[57] John Mauchly, to cite another kind of postwar security issue, was accused of being a communist sympathizer (he was not) and was denied a clearance.[58]

Though many of the military-sponsored computer projects were not classified in the direct sense, informal self-censorship remained a part of postwar academic research culture. As Paul Forman has argued, "strictly speaking there was in this [post–World War II] period no such thing as unclassified research under military sponsorship. 'Unclassified' was simply that research in which some considerable part of the responsibility for deciding whether the results should be held secret fell upon the researcher himself and his laboratory." Forman cites the ONR's Alan Waterman and Capt. R. D. Conrad, writing in 1947, to the effect that "the contractor is entirely free to publish the results of his work, but . . . we expect that scientists who are engaged on projects under Naval sponsorship are as alert and as conscientious as we are to recognize the implications of their achievement, and that they are fully competent to guard the national interest."[59]

Third, even after mature commercial computer markets emerged in the early 1960s, U.S. military agencies continued to invest heavily in advanced computer research, equipment, and software. In the 1960s the private sector gradually assumed the bulk of R&D funding. IBM, in particular, adopted a strategy of heavy investment in research, reinvesting over 50 percent of its profits in internal R&D after 1959. The mammoth research organization IBM built gave it the technical edge partly responsible for the company's dominance of the world computer market for the next two decades. To compete, other companies eventually duplicated IBM's pattern of internal research investment.

Despite the extraordinary vitality of commercial R&D after the early 1960s, the Pentagon continued to dominate research funding in certain areas. For example, almost half of the cost of semiconductor R&D between the late 1950s and the early 1970s was paid by military sources. Defense users were first to put

---

[56] Jay W. Forrester, "Computation Book," entry for 8/13/47. Magnetic Core Memory Records, 1932–1977, MC 140, Box 4, F 27. (Institute Archives and Special Collections, Massachusetts Institute of Technology, Cambridge, MA).

[57] Redmond and Smith (*Project Whirlwind*, 75) quote a letter from Warren Weaver to Mina Rees to the effect that MIT professor Samuel Caldwell "would work only 'on research concerning electronic computing that will freely serve all science,' a view shared by many of his colleagues."

[58] On Mauchly's security problems, see the Appendix to Augarten, *Bit by Bit*.

[59] Forman, "Behind Quantum Electronics," 206.

into service integrated circuits (ICs, the next major hardware advance after transistors); in 1961, only two years after their invention, Texas Instruments completed the first IC-based computer under Air Force contract. The Air Force also wanted the small, lightweight ICs for Minuteman missile guidance control. In 1965, about one-fifth of all American IC sales went to the Air Force for this purpose. Only in that year did the first commercial computer to incorporate ICs appear.[60] ICs and other miniaturized electronic components allowed the construction of sophisticated digital guidance computers that were small, light, and durable enough to fit into missile warheads. This, in turn, made possible missiles with multiple, independently-targetable reentry vehicles (MIRVs), which were responsible for the rapid growth of nuclear destructive potential in the late 1960s and early 1970s.[61] ICs were the ancestors of today's microprocessors and very-large-scale integrated circuitry, crucial components of modern cruise missiles and other "smart" weaponry.

Another instance was the nurturance of artificial intelligence (AI) by the Advanced Research Projects Agency (ARPA, later called DARPA, the Defense Advanced Research Projects Agency), which extended from the early 1960s until the final end of the Cold War. AI, for over two decades almost exclusively a pure research area of no immediate commercial interest, received as much as 80 percent of its total annual funding from ARPA. ARPA also supported such other important innovations as timesharing and computer networking. In 1983, with its Strategic Computing Initiative (SCI), DARPA led a concerted Pentagon effort to guide certain critical fields of leading-edge computer research, such as artificial intelligence, semiconductor manufacture, and parallel processing architectures, in particular directions favorable to military goals. (We will return to ARPA and its relationship with AI in chapters 8 and 9.)

Thus the pattern of military support has been widespread, long-lasting, and deep. In part because of connections dating to the ENIAC and before, this pattern became deeply ingrained in postwar institutions. But military agencies led cutting-edge research in a number of key areas even after a commercial industry became well established in the 1960s. As Frank Rose has written, "the computerization of society . . . has essentially been a side effect of the computerization of war."[62]

Why Build Computers?

---

[60] Flamm, *Creating the Computer*, 17–18. Also see Harry Atwater, "Electronics and Computer Development: A Military History," *Technology and Responsibility*, Vol. 1, No. 2 (1982).

[61] Ted Greenwood, *Making the MIRV* (Cambridge: Ballinger, 1975).

[62] Frank Rose, *Into the Heart of the Mind* (New York: Harper and Row, 1984), 36.

We have explored the origin of military support, its extent, and some of its particular purposes. Now we must return once again to the question of posed in the chapter title, this time at the level of more general institutional and technical problems. Why did the American armed forces establish and maintain such an intimate involvement with computer research?

The most obvious answer comes from the utilitarian side of the vision captured in General Westmoreland's "electronic battlefield" speech: computers can automate and accelerate important military tasks. The speed and complexity of high-technology warfare have generated control, communications, and information analysis demands that seem to defy the capacities of unassisted human beings. Jay Forrester, an MIT engineer who played a major role in developing the military uses of computing, wrote that between the mid-1940s and the mid-1950s

> the speed of military operations increased until it became clear that, regardless of the assumed advantages of human judgment decisions, the internal communication speed of the human organization simply was not able to cope with the pace of modern air warfare. . . . In the early 1950s experimental demonstrations showed that enough of [the] decision making [process] was understood so that machines could process raw data into final weapon-guidance instruction and achieve results superior to those then being accomplished by the manual systems.[63]

Computers thus improved military systems by "getting man out of the loop" of critical tasks. Built directly into weapons systems, computers assisted or replaced human skill in aiming and operating advanced weapons, such as antiaircraft guns and missiles. They automated the calculation of tables. They solved difficult mathematical problems in weapons engineering and in the scientific research behind military technologies, augmenting or replacing human calculation. Computers began to form the keystone of what the armed forces now call "C^3I" -- command, control, communications, and intelligence (or information) networks, replacing and assisting humans in the encoding and decoding of messages, the interpretation of radar data, and tracking and targeting functions, among many others.

---

[63] Jay W. Forrester, "Managerial Decision Making," in Martin Greenberger, ed., *Computers and the World of the Future* (Cambridge, MA: MIT Press, 1962), 53.

I will argue that this automation theory is largely a retrospective reconstruction. In the 1940s it was not at all obvious that *electronic digital* computers were going to be good for much besides exotic scientific calculations. Herman Goldstine recalled that well into the 1950s "most industrialists viewed [digital] computers mainly as tools for the small numbers of university or government scientists, and the chief applications were thought to be highly scientific in nature. It was only later that the commercial implications of the computer began to be appreciated."[64] Furthermore, the field of analog computation was well developed, with a strong industrial base and a well-established theoretical grounding. Finally, analog control mechanisms (servomechanisms) had seen major improvements during the war. They were readily available, well-understood, and reliable.

Howard Aiken, the Harvard designer of several early digital computers, told Edward Cannon that "there will never be enough problems, enough work, for more than one or two of these [digital] computers," and many others agreed.[65]

Analog vs. Digital: Computers and Control

Most modern computers perform three basic types of functions: calculation, communication, and control.[66] The computers of the 1940s could not yet do this; they were calculators, pure and simple. Their inputs and outputs consisted

---

[64] Goldstine, *The Computer from Pascal to von Neumann*, 251.

[65] Aiken's Mark I project was begun in 1937 and completed in 1943. Despite its large scale, neither this nor his subsequent computers had much influence on the main stream of computer development, largely due to his conservative technological approach (according to Augarten, *Bit by Bit*). Cannon reported Aiken's comment in his sworn testimony for *Honeywell v. Sperry Rand*, p. 17935, cited in Stern, *From ENIAC to UNIVAC*, 111.

[66] *Calculation* is the mathematical and logical function: crunching numbers, analyzing data, working with Boolean (true-false) variables. *Communication* includes the transfer of text, data, and images among computers through networks, electronic mail, and fax. In *control* functions computers operate other machines: telephone switching networks, automobile engines, lathes. (The control of spacecraft from Earth provides an example of how the three functions are now integrated: computers calculate trajectories and determine which engines to burn, for how long, to achieve needed course corrections. They then control the spacecraft via digital communications, translated by the spacecraft's own computer into signals controlling the jets.) While pure calculation may be done at any speed and may be interrupted and resumed without loss, communication is often and control is almost always a *real-time* function. The person listening to a radio transmission or telephone call hears it at exactly the same pace and almost exactly the same time as the person speaking into the microphone; while the communication may be interrupted and resumed, this is usually inconvenient and undesirable. The servomechanism or mechanical linkage controlling a machine such as a car operates at exactly the same pace as the machine itself. If such control is interrupted, the machine stops or, worse, continues to operate "out of control."

exclusively of numbers or, eventually, of other symbols printed on paper or punched on cards. In most of the first machines, both decimal numbers and instructions had to be translated into binary form. Each computer's internal structure being virtually unique, none could communicate with others. Neither (with the exception of printers and card punches) could they control other machines.

Deep theoretical linkages among the three functions were already being articulated in the communication and information theories of Norbert Wiener and Claude Shannon. But these theoretical insights did not dictate any particular path for computer development. Nor did they mandate digital equipment. The idea of combining the three functions in a single machine, and of having that machine be an electronic digital computer, came not just from theory -- both Shannon and Wiener, for example, were also interested in other types of machines[67] -- *but from the evolution of practical design projects in social and cultural context.*

The idea of using digital calculation for control functions involved no special leap of insight, since the role of any kind of computer in control is essentially to solve mathematical functions. (Indeed, the RCA engineer Jan Rajchman attempted to construct a digital fire-control computer for antiaircraft guns in the early 1940s.)[68] But unlike then-extant digital machines, analog computers integrated very naturally with control functions, since their inputs and outputs were often signals of the same type as those required to control other machines (e.g., electric voltages or the rotation of gears).[69] The conversion of data into and out of numerical form thus constituted a difficult extra step that could often be bypassed. In addition, because many electrical devices, including vacuum tubes, have analog as well as digital properties, the increasing shift from electro-mechanical to electronic control techniques had little bearing on the question of digital vs. analog equipment. In fact, some of the wartime analog computers, such as Bush's RDA and the Bell gun directors discussed below, used electronic components.[70] Finally, the wartime investment in digital computing

---

[67] Shannon, for example, presented an analog maze-solving machine to the eighth Macy Conference. Heinz von Foerster, ed., *Transactions of the Eighth Conference on Cybernetics* (New York: Josiah Macy Jr. Foundation, 1952), 173–180. Also see Shannon, "Computers and Automata," *Proceedings of the IRE*, Vol. 41 (1953), 1234–1241. Norbert Wiener, *Cybernetics* (Cambridge, MA: MIT Press, 1948), describes a wide variety of devices; after the war Wiener became deeply interested in prosthetics.

[68] See Jan Rajchman, "Early Research on Computers at RCA," in Metropolis, Howlett, and Rota, *A History of Computing in the Twentieth Century*, 465–469.

[69] David Mindell has recently argued that Bush's Differential Analyzer was not primarily a calculating engine, but a real-time control system. See David Mindell, "From Machinery to Information: Control Systems Research at MIT in the 1930s," paper presented at Society for the History of Technology Annual Meeting, Lowell, MA, 1994, 18.

[70] The future role of digital equipment in communication itself was also far from clear, since almost all electronic communication technologies after the (digital) telegraph employed (analog)

represented by ENIAC shrank into insignificance when compared with the wartime program in radar and control systems research, which were primarily analog technologies, with the result that far more engineers understood analog techniques than grasped the new ideas in digital computing.

Many of the key actors in computer development, such as Bell Laboratories and MIT, had major and long-standing investments in analog computer technologies. For example, in 1945, as the ENIAC was being completed, Bell Labs was commissioned to develop the Nike-Ajax antiaircraft guided missile system for the Army. Bell proposed a "command-guidance" technique in which radar signals would be converted into missile guidance instructions by ground-based analog computers.[71] Likewise, one of MIT's major wartime research groups was the Servomechanisms Laboratory, which built analog control devices for antiaircraft gun directors and other uses.[72]

With a vigorous tradition of analog computation and control engineering already in place after the war, work proceeded rapidly on general-purpose electronic analog computers. A number of mammoth machines, such as RCA's Typhoon, were constructed under both corporate and military sponsorship. Mina Rees, then director of the ONR's Mathematical Sciences Division, noted in a 1950 public report on federal support for computer research that the ONR continued to fund a variety of analog machines. She pointed to the robust health of the analog computer and control industry as one reason the ONR's analog program was not even larger. "There is," she pointed out, "vastly more analog than digital equipment that has been built without government support, but . . . the government and its contractors make extensive use of the equipment." Rees also praised the "broad point of view that recognizes merit in both the analog and the digital aspects of the computer art."[73] Analog engineers thought their computers could compete directly with digital devices in any arena that did not demand enormous precision.

These machines and the social groups centered around them (such as industrial research laboratories, university engineering schools, and equipment manufacturers) constituted a major source of resistance to the emerging digital

waveforms, converting sound waves into radio or electrical waves and back again. However, digital switches -- relays -- were the primary *control* elements of the telephone network, and a source of some of the early work on digital computers. As we will see in chapter 8, Claude Shannon's wartime work on encryption of voice transmissions produced the first approaches to digitizing sound waves.

[71] C. A. Warren, B. McMillan, and B. D. Holbrook, "Military Systems Engineering and Research," in Fagen, *A History of Engineering and Science in the Bell System*, 618.

[72] 40,000 of the analog 40mm gun directors designed by the Servomechanisms Lab were manufactured during the war. Its budget, by the war's end, was over $1 million a year. Wildes and Lindgren, *A Century of Electrical Engineering and Computer Science at MIT*, 211.

[73] Mina Rees, "The Federal Computing Machine Program," *Science*, Vol. 112 (1950), 732. Reprinted in *Annals of the History of Computing*, Vol. 7, No. 2 (1985), 156–163.

paradigm, especially when it came to using the new machines for purposes other than mathematical calculation. In the words of one participant,

> Analog computer experts felt threatened by digital computers. World War II, with its emphasis on automatic pilots and remotely controlled cannon, fostered the analog computer-servo engineering profession. . . . Many analog computer engineers were around following the war, but so great was the newly realized demand for control devices that the colleges began training increasing numbers. . . . [O]nly a relatively few servo engineers were able to make the transition to digital machines. . . . In 1945 . . . we confidently expected that factories would have become softly humming hives of selsyn motors, amplidyne generators and analog computers by the year 1960.[74]

Even as late as 1950, among the groups then developing digital machines, the heritage of World War II analog equipment proved difficult to overcome. When a Rand team seeking a programmable digital machine toured the country's major computer projects, "what [they] found was discouraging." Many of the groups working on reliability and high-speed computing were exploring "modifications of radar technology, which was largely analog in nature. . . . They were doing all kinds of tweaky things to circuits to make things work. It was all too whimsical."[75]

In addition to social inertia, easy availability, and an acculturated preference for analog technology, there were many other reasons why sophisticated engineers might reject electronic digital computers for most purposes during the 1940s and early 1950s. First, the electronic components of the day were not very reliable. As we have seen, most scientists scoffed at the idea that a machine containing vast numbers of vacuum tubes could ever function for more than a few minutes at a time without breaking down. Thus to contemplate using electronic digital machines for control functions, in real time and in situations where safety and/or reliability were issues, seemed preposterous to many. Second, early electronic computers were huge assemblies, the size of a small gymnasium, that consumed power voraciously and generated tremendous heat. They often required their own power supplies, enormous air conditioners, and even special buildings. Miniaturization on the scale we take for granted today had not emerged even as a possibility. Third, they were

---

[74] George E. Valley Jr., "How the SAGE Development Began," *Annals of the History of Computing,* Vol. 7, No. 3 (1985), 218.

[75] Fred J. Gruenberger, "The History of the JOHNNIAC," *Annals of the History of Computing,* Vol. 1, No. 1 (1979), 50.

extremely expensive (by the standards of analog equipment), and they demanded constant and costly maintenance. Finally, early electronic computers employed exotic materials and techniques, such as mercury delay line memory and the cantankerous electrostatic storage tube, which added their own problems to the issues of cost and reliability.

Even once it became clear (in the late 1940s) that electronic digital computers would work, could be made reasonably reliable, and could operate at speeds far outstripping their mechanical and electro-mechanical counterparts, another issue prevented them from being seriously considered for control functions. As George Valley, one of the leaders of the SAGE project, pointed out in a 1985 retrospective, "relatively few wanted to connect computers to the real world, and these people seemed to believe that the sensory devices would all yield *data*. In fact, only some sensors -- such as weighing machines, odometers, altimeters, the angle-tracking part of automatic tracking radars -- had built-in counters. Most sensory devices relied on human operators to interpret noisy and complex signals."[76] The problem lay in designing sensory devices that produced direct numerical inputs for the computer to calculate with. Analog control technologies did not require such conversions, because they represented numerical quantities directly through physical parameters.[77]

In 1949, according to Valley, "almost all the groups that were realistically engaged in guiding missiles . . . thought exclusively in terms of analog computers."[78] A notable exception was the Northrop Snark missile project, which engaged Eckert and Mauchly to build the BINAC digital computer, completed in 1949, for its guidance system. However, the BINAC did not work well, and Northrop engineers afterward moved toward special-purpose digital differential analyzers -- and away from stored-program general-purpose computers -- for the project.[79]

As late as 1960 Albert Jackson, manager of data processing for the TRW Corporation, could write with authority, in a textbook on analog computation,

---

[76] Valley, "How the SAGE Development Began," 207. Italics added.

[77] A simple example can illustrate this point. An ordinary thermostat is an analog control device with a digital (on / off, discrete-state) output. A coiled bimetal strip inside the thermostat varies in length continuously with the ambient temperature. To it is affixed a horizontal tube containing a drop of mercury. As the temperature drops, the coil shrinks and the tube tilts past the horizontal. This causes the mercury to flow to one end of the tube, closing an electrical connection that activates the heating system. As the temperature then rises, the coil slowly expands, the tube eventually tilts the other way, and the mercury flows to its other end. This deactivates the switch, and the heater turns off. This device might thus be said to compute a function: if temperature $t \leq$ temperature setting s, heater setting $h = 0$ (off). If $t < s$, $h = 1$ (on). This function *could* be computed using numerical inputs for t and s. But since the function is represented directly in the device, no conversion of physical quantities into numerical values is required.

[78] Valley, "How the SAGE Development Began," 206.

[79] See Stern, *From ENIAC to Univac.*

that electronic analog computers retained major advantages. They would always be better at control functions and most simulations, as well as faster than digital devices.

> The [general-purpose] electronic analog computer is a very fast machine. Each operational unit can be likened to a digital arithmetical unit, memory unit, and control unit combined. Since as many as 100 to 500 of these units will be employed in parallel for a particular problem setup, it can be seen why an analog computer is faster than a digital machine, which seldom has more than one arithmetical unit and must perform calculations bit by bit or serially. Because of their high speed, electronic analog computers have found wide application as *real-time* simulators and control-system components.

Only in the 1980s did efficient *digital* parallel processing become possible, motivated in part by precisely this issue of real-time control. Jackson continued:

> In conclusion, analog computers have found and will continue to find wide application to problems where the knowledge of the physical situation does not permit formulation of a numerical model of more than four significant digits or where, even if such a model could be designed, the additional time and expense entailed in digital computation would not be warranted because of other factors.[80]

Clearly, in the decade following World War II digital computers were a technology at the early phase of development that Trevor Pinch and Wiebe Bijker describe as, in essence, a solution in search of a problem. The technology of digital computation had not yet achieved what they call "closure," or that state of technical development and social acceptance in which large constituencies generally agree on its purpose, meaning, and physical form.[81] The shape of computers, as tools, was still extremely malleable, and their capacities remained to be envisioned, proven, and established in practice. Thus the use of digital devices to create automated, centralized military command-control systems was anything but foreordained.

---

[80] Albert S. Jackson, *Analog Computation* (New York: McGraw-Hill, 1960), 8.

[81] Trevor Pinch and Wiebe Bijker, "The Social Construction of Facts and Artifacts," in Bijker, Hughes, and Pinch, *The Social Construction of Technology,* 17–50.

Computers Take Command

The utilitarian account of military involvement in computer development also fails to explain one of the major paradoxes of military automation. Computers were used first to automate calculation, then to control weapons and guide aircraft, and later to analyze problems of command through simulation. The final step in this logic would be the eventual automation of command itself; intermediate steps would centralize it and remove responsibilities from lower levels. Military visionaries and defense intellectuals continually held out such centralization as some kind of ultimate goal, as in General Westmoreland's dream of the electronic battlefield. By the mid-1980s, DARPA projects envisioned expert systems programs to analyze battles, plot strategies, and execute responses for carrier battle group commanders. The Strategic Computing Initiative program announcement claimed that in "the projected defense against strategic nuclear missiles . . . systems must react so rapidly that it is likely that almost complete reliance will have to be placed on automated systems" and proposed to develop their building blocks.[82] DARPA's then-director Robert Cooper asserted, in an exchange with Senator Joseph Biden, that with sufficiently powerful computers, presidential errors in judgment during a nuclear confrontation might be rendered impossible: "we might have the technology so he couldn't make a mistake."[83]

The automation of command clearly runs counter to ancient military traditions of personal leadership, decentralized battlefield command, and experience-based authority.[84] By the early 1960s, the beginning of the McNamara era and the early period of the "electronic battlefield," many military leaders had become extremely suspicious of the very computers whose development their organizations had led. Those strategists who felt the necessity and promise of automation described by Jay Forrester were opposed by others who saw that the domination of strategy by preprogrammed plans left no room for the extraordinarily contingent nature of battlefield situations. In 1964, Air Force Colonel Francis X. Kane reported in the pages of *Fortune* magazine that "much of the current planning for the present and future security of the U.S. rests on

---

[82] Defense Advanced Research Projects Agency, *Strategic Computing* (Washington, DC: Defense Advanced Research Projects Agency, 1983), 8.

[83] Jonathan Jacky, "The Strategic Computing Program," in David Bellin and Gary Chapman, eds., *Computers in Battle* (New York: Harcourt Brace, 1987), 184.

[84] For entrées to the large literature on this topic, see Gary Chapman, "The New Generation of High-Technology Weapons," in Bellin and Chapman, *Computers in Battle*, 61–100; Chris Hables Gray, *Computers as Weapons and Metaphors: The U.S. Military 1940–1990 and Postmodern War* (unpublished Ph.D. thesis, University of California, Santa Cruz, 1991); and Morris Janowitz, *The Professional Soldier* (Glencoe, IL: Free Press, 1960).

computerized solutions." It was, he wrote, impossible to tell whether the actual results of such simulated solutions would occur as desired, because

> we have no experience in comparing the currently accepted theory of predicting wars by computer with the actual practice of executing plans. But I believe that today's planning is inadequate because of its almost complete dependence on scientific methodology, which cannot reckon with those acts of will that have always determined the conduct of wars. . . . In today's planning the use of a tool -- the computer -- dictates that we depend on masses of data of repeated events as one of our fundamental techniques. We are ignoring individual experience and depending on mass experience instead.[85]

Also in the early 1960s occasional articles in the armed forces journal *Military Review* began warning of "electronic despotism" and "demilitarized soldiers" whose tasks would be automated to the point that the men would be deskilled and become soft.[86] Based on interviews with obviously disaffected commanders, *U.S. News & World Report* reported in 1962 -- under the banner headline "Will 'Computers' Run the Wars of the Future?" -- that "military men no longer call the tunes, make strategy decisions and choose weapons. In the Pentagon, military men say they are being forced to the sidelines by top civilians, their advice either ignored or not given proper hearing. . . . In actual defense operations, military commanders regard themselves as increasingly dependent on computer systems."[87] While these reports certainly exaggerated the actual role of computers in military planning and especially in military operations at the time, their existence shows that the view of computers as a solution to military problems faced internal opposition from the start. They also demonstrate how deeply an ideology of computerized command and control had penetrated into U.S. military culture.

The automation theory alone, then, explains neither the urgency, the magnitude, nor the specific direction of the U.S. military effort in computing. Rather than explain how contests over the nature and potential of computers were resolved, a utilitarian view writes history backwards, using the results of those contests to account for their origins.

---

[85] Colonel Francis X. Kane, USAF, "Security Is Too Important To Be Left to Computers," *Fortune,* Vol. 69, No. 4 (1964), 146–147.

[86] Ferdinand Otto Miksche, "The Soldier and Technical Warfare," *Military Review*, Vol. 42, No. 8 (1962), 71–78; Major Keith C. Nusbaum, U.S. Army, "Electronic Despotism: A Serious Problem of Modern Command," *Military Review*, Vol. 42, No. 4 (1962), 31–39.

[87] "Will 'Computers' Run Wars of the Future?," *U.S. News & World Report* (April 23, 1962), 44–48.

Nor does a utilitarian view explain the pervasive military *fascination* with computers epitomized by General Westmoreland's speech in the aftermath of Vietnam. "I see," he proclaimed, "an Army built into and around an integrated area control system that exploits the advanced technology of communications, sensors, fire direction, and the required automatic data processing -- a system that is sensitive to the dynamics of the ever-changing battlefield -- a system that materially assists the tactical commander in making sound and timely decisions."[88] This is the language of vision and technological utopia, not practical necessity. It represents a dream of victory that is bloodless for the victor, of battle by remote control, of speed approaching the instantaneous, and of certainty in decision-making and command. It is a vision of a closed world, a chaotic and dangerous space rendered orderly and controllable by the powers of rationality and technology.

Why build computers? In this chapter I have tried to show that not only the answers, but also the very question, are complex. Their importance to the future of U.S. military power was by no means obvious at the outset. To understand how it became so, we must look closely at the intricate chains of technological advances, historical events, government policies, and emergent metaphors comprising closed-world discourse. For though policy choices at the largest levels determined research directions, in some cases quite specifically, defining digital computation as relevant to national priorities was not itself a policy issue. Instead it involved a complicated nexus of technological choices, technological traditions, and cultural values. In fact, digital computer research itself ended up changing national priorities, as we will see in the following chapters.

---

[88] Westmoreland, "Address," 222.