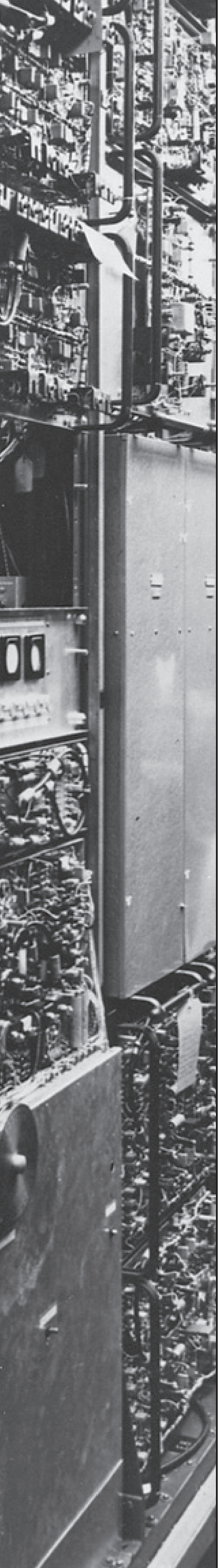

Chapter One

On the Road to Find Out

You can't really guess where mind-amplifying technology is going unless you understand where it came from.

—Howard Rheingold, *Tools for Thought*

Bright Boys is a story about technology when technology was young: 1938–1958. Two decades that ushered in the new world of electronics. A remarkable 20 years when computers were giants, their makers young and unknown, and when there was less than a megabyte of random access memory on the entire planet. Microprocessors were science fiction; transistors were handmade and mistrusted; and banks of hot, glowing electron tubes ruled the land. Networks were meant only for telephones and electric power grids, and the word "digital" was new on the ear. Yet it came as no surprise to a band of bright boys that these two decades would change everything and that they would play an enormous part in getting it all started.

Their first decade was filled with guesses, probings, and dawnings. The second was a near-magical time of incredible emergences as, almost simultaneously, information theory came of age, digital computing first appeared, networking was born, and the first glimmerings of Information Technology edged into existence. Astonishing was the convergence of information, digital computing, and communications wrought by a bunch of cocky, twentysomething engineers, who thought they could do most anything they turned their hands to, and usually did. Others contributed mightily to the convergence as well: brilliant aviators from the Air Corps Tactical School at Maxwell Field, Alabama; radar pioneers from Ft. Monmouth, New Jersey; and physicists from MIT's wartime

Interior of Barta Building and Whirlwind computer; Jay Forrester with Norman Taylor. (Photo courtesy of MITRE Corporation.)

Radiation Laboratory. Theirs was an amazing bucket brigade of bright boys handing along their intellectual toil from one to the other, from one decade into the next. Equally amazing and improbable was that these same bright boys would themselves eventually converge, gathering together with their ideas and energy in the most unlikely of places: an old, rundown former laundry building in Cambridge, Massachusetts, a few hundred yards from the banks of the Charles River.

The Charles is at its widest where it separates the city of Boston from that of Cambridge. Massachusetts Avenue and its bridge—known locally by the same name, but actually Harvard Bridge—link both. On the Cambridge side, a stone's throw from the front entrance of MIT, is 211 Massachusetts Avenue, an ornate, hundred-year-old, brick building that when first erected in 1904 was known as the E&R Laundry Company, and then, much later, called the Barta Building, after a publisher by the same name. From the bare floor of that vacant factory the bright boys launched the country on one of the greatest and most successful projects in the history of American engineering. No similar enterprise had ever or has since sprung from such humble surroundings.

If they had brought forth only the first real-time digital computer, the first digital network, and the first practical application of information theory, as they did, and produced nothing thereafter, their adventure would have been a colossal triumph. However, their string of startling successes rambled on.

They were the first to develop an electronic digital computer capable of controlling other machines and processes, a distinctly radical departure from the handful of other electronic computers of the day that calculated numbers only and then regurgitated an answer. They pioneered the highly complex and very chancy process of engineering multiple electronic systems together into a single system. They were the first to institutionalize quality control from R&D to prototyping to manufacturing and on into management. They originated modular construction of computers. They invented the modem and taught AT&T how to use it. They conceived of IBM's first computer assembly line. They originated computer memory that became the industry standard until the 1970s. They launched the formal development of software programming. And like major, high-tech corporations years into the future, they designed and prototyped most everything yet manufactured next to nothing, preferring to outsource all production and supply. Theirs was a profusion of technological firsts that is as yet unmatched in any single engineering project since.

When all the bright boys first gathered together there was no telling what would transpire in that old factory when youth, intelligence, energy, and pluck were implored by their country to do the impossible, like figure out a way to defend the skies over North America from enemy bombers. By 1950, these young MIT-trained engineers and their cohorts from the United States Air Force were given that exact challenge—with the added proviso to get the job done in a hurry. Their task was especially urgent because the Soviet Union had just detonated its first-ever atomic bomb and had unveiled a fleet of long-range Tupelov bombers readily capable of delivering deadly payloads into the heartland of America. Their task was especially important in that no such air defense even remotely existed and very few had even a vague notion of how to make one. Many people, some influential, dismissed their task as impossible and an utter waste of government money. Still others, some of whom were influential believers but fearful of the new technology, inveighed mightily against their attempts to build it. In short, it was a perfect scenario for the making of the future, and the bright boys were not about to disappoint.

For sheer size, the bright boys' undertaking was rivaled only by the Manhattan Project; and for sheer innovation, its scads of brilliant inventions were for decades thereafter without peer. If the country had pinned its hopes on the Manhattan Project to end a war, its trust was pinned on the bright boys to help save a world. They not only made the impossible possible for the skies over North America, but, in the process, also ushered in the military's long sought after yet previously elusive prize, real-time command and control. And as if that wasn't enough of a success, they poked a gaping hole in the future and dragged into being the modern world of Information Technology.

Initially, the bright boys had little idea what exactly it was they dragged in through that gaping hole. Their search was for how best to manipulate digital information for air defense using their newly hatched creation, the Whirlwind computer, a monster of a machine that filled an entire floor of the Barta Building. Information Technology, a term not yet coined, was an unexpected consequence of that primary objective. Although they pioneered Information Technology, the closest they got to a name for their work was "real-time command and control," which was the information engine for how air defense went about spotting far off enemy bomber formations and getting interceptors after them. However, scratch the surface just about anywhere over the enormous swath of Information Technology—from email to file transfer to smart bombs over Baghdad—and there gleaming back up is the unmistakable DNA of real-time command and control.

Each time we spin a CD, step off an elevator, book an airplane ticket, get cash from an ATM, or even pop a steak into a microwave, there's an unseen thread that leads directly back to the bright boys' inner sanctum of discovery and innovation. Of course, now everyone and everything is bound up in the clutches of this all-pervasive, all-powerful Information Technology. Popularly known to most as just IT, Information Technology is that high-tech panoply of computers, telecommunications, and the myriad devices that digitally connect and integrate information, equipment, and people. Beginning with the bright boys' first information loom, built and cranked into action in the old factory near the Charles, these two initials have subtly yet inexorably woven themselves into the fabric of our lives.

Today there are information looms everywhere, atop our desks, on our laps, and in our pockets and purses. Many of us spend most of our waking hours spinning information on them, creating, shaping, and forming information as needed, then sending it at the speed of light everywhere and anywhere at any time to anyone of our choosing. As the *Stanford Encyclopedia of Technology* sees it, Information Technology's fingers are into everything, essentially all the "collecting, storing, encoding, processing, analyzing, transmitting, receiving, and printing of text, audio, or video information." That covers just about everything we do in today's digital world, including helping us to earn a living, raise a family, and enjoy ourselves.

We've gone so far as to define our times as an information age, an information economy, an information society, or an information revolution. Not so in the world that swirled around 211 Mass Ave. Back then there was a pristine simplicity to the notion of information. Even as late as the mid-1940s, information was meant mostly for the likes of the US Census Bureau every ten years, banks, and insurance actuaries. There were, in all of the technical and scientific literature for 1946, only seven articles on information.[1] The word "information" seems simple enough, deriving from the Latin, *informare*, meaning, "to put into form." However, as the *Stanford Encyclopedia of Technology* makes us aware, when the word "technology" is appended to the word "information," all hell breaks loose. Today the word "information" has taken on a whole new spin: it's anything and everything . . . and it's powerful. Charles Seif, the well-known physicist and journalist, likens us to information beings. "Each creature of the Earth," he writes in *Decoding the Universe*, "is a creature of information; information sits at the center of our cells, and information rattles around in our brains."[2] The book's subtitle hammers home that conviction: *How the New Science of Information is Explaining Everything in the Cosmos, from Our Brains to Black Holes*. No one in 1946 could ever have fathomed how transmuted information would become when mixed in the crucible of technology. The bright boys were as startled as any.

Technology in a Foxhole

If the civilian world was clueless about information, the world of the military was not far behind. Information needs for the military were immediate and vital, and it was agonizingly slow in recognizing the emerging information paradigm. Anyone who has ever peered over the top of a foxhole toward enemy lines has a healthy reverence for information. What's the enemy up to? Will they attack? If so, when and where? What are their numbers? What kinds of weapons do they have? Can we match up with them? Can we beat them? The military has an unending supply of questions about an adversary's everything that all need quick, accurate answers.

It's a natural reaction considering that outcomes like injury, capture, or death can result from bad or slow or nonexistent information. The problem with military information was that it hardly ever arrived in real time, was nearly always fragmentary, and of inconsistent quality. Without solid information with which to analyze a potential threat or to get a clear understanding of what's happening on a battlefield, victory and lives were always in great jeopardy. For millennia the struggle to gain an information advantage over an enemy was as desperate as the fighting itself.

Bright Boys is also a story about how the military got savvy about real-time information and how to acquire it. It was the United States Air Force that first stumbled upon the great teacher in the old laundry building and came to realize the information potential of the huge machine. That encounter sparked a revolution in military affairs known as real-time command and control. It transformed the Air Force from a staunch computer disbeliever "to the leading advocate of computerization in the military."[3] But the transformation did not come easily. Although code breaking and espionage were tangible enough information sources, it was difficult for the military to comprehend that an information advantage might actually be a weapon—maybe even the ultimate of weapons.

Weapons were supposed to be things that one held or rode or loaded with shells. A B-17 glinting in the sunlight and bristling with power was a real weapon, or so they thought. A couple of bright boy aviators in the late 1930s, information zealots who challenged an engrained "bomber mafia," paid dearly for their stubborn belief in the primacy of information over cold steel. Years later, one of them would eventually struggle his way into the old laundry building to finally prove the point. Time and technology have now shown the military how right the two zealots were.

"Information technology," Bruce Berkowitz, the former CIA analyst, hailed in his groundbreaking *The New Face of War*, "has become so important in defining military power that it overwhelms almost everything else."[4] A belief now held fast by none other than the United States Department of Defense as "central to greater battlefield awareness, enabling our forces to acquire large amounts of information, analyze it quickly, and communicate it to multiple users simultaneously for coordinated and precise action."[5]

In order to get a leg up on an adversary, armies have for millennia sought out two kinds of information. Strategic information is gained well before any guns go off about the intentions or plans that an enemy is hatching. Learning the intentions of the Japanese high command before the Imperial fleet set sail for Pearl Harbor would have been of great strategic value. On the other hand, tactical information is more immediate. It's early warning, like finding out in the nick of time that Admiral Yamomoto's dive bombers were revving their engines on carrier flight decks. Good, real-time information, what the military calls "actionable information," can mean the difference between victory and defeat. In 490 BC Phidippides ran 26 miles to Athens to carry tactical information of the Greek victory at Marathon and to warn about Persian ships approaching Athens. Sun Tzu, the Wu Dynasty's very winning general from the sixth century BC, had his information-gathering techniques put into book form, *The Art of War*. Knowing his enemy was all-important to Sun Tzu, and he went to extraordinary lengths to gather both strategic and tactical information. To save wear and tear on himself and his army, Sun Tzu believed in the power of gaining advantage through strategic information. *The Art of War* devotes a chapter to spies, double agents, espionage, and counterespionage.

It wasn't until the unimaginable carnage of World War I that militaries fell upon a way to get a fast, consistent, and dependable information edge on their enemies. A stalemate between opposing barbed-wire trenches for years on end with new weapons of war like machine guns, tanks, poison gas shells, lightweight mortars, and long-rage artillery taking an hourly toll of each nation's best was the agent of change. Flimsy biplanes with on-board cameras snapping pictures of battlefields provided the information breakthrough. A picture is worth a thousand words, and an aerial photo of enemy positions might well save thousands of lives . . . and maybe even win a war. The flimsy biplanes gave way to the rise of air power and the flimsy cameras to the rise of aerial reconnaissance. Suddenly planes got faster, war got faster, and pictures alone were not enough.

Code breaking was faster still and very stealthy. Breaking the Japanese naval cipher JN-25 ensured victory at the Battle of Midway, as did similar success with the German's Enigma code help to shorten the war in Europe. Both successes came courtesy of a machine: a whirring, clinking, gear-laden analog device that did not drop bombs or spew out rounds of bullets, rather, it spewed out information. And the information it produced was powerful: it changed events; it changed history. How powerful an information weapon was it to know in advance an enemy's every move? Heady stuff indeed for any general to command. Yet somehow these clanking beasts of information never evolved up to the next level. They were limited in their capabilities. They seemed stunted from birth. Something else was needed.

The Something Else

In the faint pre-dawn glow of the Digital Age—the mid- to late-1940s—electronic digital computers had much in common with Jurassic dinosaurs: large in body but very short on brainpower. Staggering behemoths of hardware, most were about the size of a gymnasium, yet with barely a fraction of the capability of a modern desktop PC. Hardly anyone gave much thought to an electronic digital computer doing anything more than munching huge quantities of numbers and then slowly regurgitating an answer. Hardly anyone, that is, except for a cocky bunch of bright boys.

Preceding the bright boys by nearly a decade and a half was the military's ongoing pursuit of improving air command and control: the ability to detect enemy planes and then to vector fighters to intercept them. In an age of jets and nuclear threat, it had grown too slow and cumbersome a process to be effective. To exert command and control in real time—as events were actually taking place—was the key objective. First manifesting itself in the minds of two Army Air Corps officers in 1935, command and control's 15-year quest for speed and accuracy would converge with the development of air defense in the old laundry building.

It's a saga of connections and crosscurrents, people and events crisscrossing through recent history. The accretion of events, roughly from 1938 to 1958, at once political, military, scientific, technological, and socioeconomic, begat its very own culture—a real-time command and control culture—which when it reached critical mass spawned a revolution in engineering. Playing out roles are air battles from the Spanish Civil War, B-17 raids over Europe during World War II, brilliant but obscure engineers in research labs, radar and radios, digital computing, information theory, cybernetics, and a fate-filled meeting in 1949 at a Pentagon taxi stand. Through grit, hard work, a little derring-do, pure genius, and out-and-out good luck, this emergent culture forged an elusive idea into a technological marvel. The pursuit of air defense would bring forth real-time command and control, which, in turn, would become the undisputed lion in all of military affairs and permeate every facet of modern Information Technology.

Air defense began more like an ever-expanding idea than a buttoned-down, ready-to-go engineering plan. The end purpose of all the putting forth was the supposed creation of a real-time, electronic command and control system capable of ensuring the detection, tracking, and interception of any number of incoming enemy bombers anywhere and at any time over the skies of the continental United States. A tall order. Many thought it wild-eyed fantasy more appropriate to comic books of the time like *Tom Corbett: Space Cadet*.

Even the customer, the United States Air Force, had grave reservations. The Air Force think tank, the RAND Corporation, issued a 1948 study highly dubious of air defense.[6] Caution seemed the better choice. Why bet the farm on something as fantastically speculative as what a small group of individuals had in mind? For here were a bunch of bright engineers and a cadre of beyond-loyal Air Force officers, who seriously considered yoking a brand new technology like digital computing—which was fighting for its own survival with the well-accepted analog computer—to World War II-era radar units, all connected by telephone lines over which would travel digital radar data. All of it brazenly new and heretofore never attempted.

Rising up and over the storm and stress from such an engineering adventure, a command and control culture began to emerge. A culture developed that integrated both the internal events of the technology with the history of the external forces acting upon that technology—what Donald MacKenzie in *Inventing Accuracy* terms "heterogeneous engineering,"[7] whereby a technological advance cannot be isolated from its social circumstances. The social and physical worlds were engineered together, giving rise to a new set of ideas, skills, and knowledge as well as devices. An original bright boy, who much later became president of the MITRE Corporation, Robert Everett, spent the better part of a lifetime actively engaged within the culture. He points out that the once brazenly new undertaking "was the predecessor of military C3 systems [command, control and computers], air-traffic control, and other large computer-based systems."[8] Indeed, this inchoate command and control culture would in short order bring forth technological wonders beyond all reckoning. Prefigured within its small, humble beginnings were entire future industries.

The need to engineer together a radar system over a telephone system to a digital computer system—and the scrupulous systems management necessary for such an intricate process—would pioneer a revolutionary new idea in engineering called the *systems approach*. This new method of complex systems building—and the tying of it all together through systems integration—would become absolutely vital to all subsequent large-scale engineering undertakings, especially the ICBM, space satellite, and NASA projects. And emerging with it came the culture's very own discipline, systems engineering: the quintessential competency for every well-schooled, high-tech engineer. Command and control's influence, through its development tools, people, and devices, would also answer the call to the military's search for a survivable, bombproof communications system by spawning the quest for its most compelling progeny, the Internet.

"The unique confluence of military, political, economic, and technological circumstances in the 1950s," writes Thomas Hughes in *Rescuing Prometheus*, "brought a decade of managerial and technological achievement that has lastingly influenced the character of American engineering and management."[9] The fervor of systems building, although primarily attendant on government and military projects, also tried casting its tendrils into the public sector. Large sections of Hughes' book chronicle the attempts—mostly unsuccessful—of migrating the systems approach to social and public works projects for state and local governments during the late 60s and early 70s. Intellectually, the systems approach had strong potential for rebuilding, say, urban housing developments or in devising public transportation systems. In reality, however, it turned out to be the right message, but from the wrong messenger. A systems builder working on single-focused, big engineering projects like the Atlas rocket just couldn't cotton to dealing with politicians, interest groups, community activists, citizens' committees, and all the other energy-sapping denizens of city bureaucracy.

Yet another tendril curled its way into the realm of business management. Thomas Haigh's paper, "Lost in Translation: Total Systems from War Room to Board Room, 1954–1968," points out the profound influence of systems engineering on the Management Information System (MIS) or the Total Systems Concept movement in business management beginning in the late 1960s. Haigh then traces the clear line of ascent as the Total Systems Concept movement transforms itself into that most bandied-about of today's *digi*-terms, the ubiquitously well-worn *Information Technology*—better known as IT.[10] Ads for UNIVAC computers appeared in 1965 issues of *Fortune* and *Business Week* touting "with a UNIVAC Total Management Information System . . . centralized control of decentralized operations becomes a reality." In 1948, however, the future importance of such a command and control culture and its staggering array of future spin offs were in little evidence and any potential outcome from its efforts was looked upon with great skepticism.

Fortunate too for the undertaking was that it sooner rather than later attracted a deep-pocketed, foursquare customer that believed much, risked much, and involved itself passionately with the project. The United States Air Force, belatedly disregarding the RAND warnings, finally anted up the cash and the nerve to get it all going. A very technologically oriented and enlightened military early on was the Army Air Service, and later under the great air power visionary, General Henry "Hap" Arnold, the then Air Force jumped in up to its chin for real-time command and control, eventually riding its big investment literally to the stars. As Arnold noted to General Bernard Schriever, the brilliant and indefatigable master builder of the Air Force space program, World War I had been won by brawn, World War II through superior logistics, but that any future war would be won by brains.[11] As "Shock and Awe" headlines in 2004 about the precision hell delivered on Iraq would amply show, the Air Force learned well: smart munitions and smart aircraft breed smart tactics. The "smarties" who began it all in their dowdy building in Cambridge squeezed the cloud of skepticism that loomed over them and turned it into a rainbow.

The development kernel within this emerging culture was a model for how Vannevar Bush, President Roosevelt's chief scientist and director of the Office of Scientific Research and Development (OSRD) during World War II, thought postwar research should go. Immediately following the war, he pushed for his vision of a civilian-controlled National Research Institute to provide for all of the country's needs. OSRD's own wartime successes like the proximity fuse, microwave radar, and the vaunted Manhattan Project, he argued, were stellar examples of the military and civilians working together. As the saying goes: "the atomic bomb ended the war but radar won it." Such a sentiment speaks volumes to the results of his development methodology as well as to the impact of science and engineering on the ensuing Allied victory. Bush cajoled and chided civilian engineers and scientists, military officers, and government officials into trusting one another to work together for a common goal. The results, well, they're known as V-E Day and V-J Day. However, just as OSRD's World War II successes had shown that disbelief to discovery was the natural order of great things, real-time command and control was no different, except that it lacked a world war to silence its doubters.

The making of real-time command and control, although sometimes contentious and fraught with difficulties, stayed true to the OSRD formula. Many of the young engineers working on command and control for the Air

Force knew Professor Bush from their undergraduate days at MIT. Some, as Bush protégés, had worked on his electromechanical analog computer, the Differential Analyzer. Still others had labored on Bush-supervised OSRD projects during the war. Through it, however, all came to fully realize and believe that it is not the brilliant researcher working in isolation who alone owns the cry of *Eureka!* Rather, it's a team.

The team of bright boys holding forth in their old factory did not have the desperation of a world war to drive their cause, but they did have the ever-escalating peril of postwar world events: Cold War clashes like the Berlin Airlift of 1948, the Soviet atomic bomb blast and intercontinental TU-4 bomber in 1949, the fall of China the same year, the Korean War from 1950 to 1954, and the Soviet Sapwood ICBM and then Sputnik—both in 1957. The resulting national frenzy from each event ratcheted up the hysteria enough to secure sizeable development dollars for the military.

The American public began looking skyward with great apprehension. Air raid sirens blared atop schools and public buildings in weekly tests, and school kids practiced hiding under their desks. Bomb shelters were all the rage while a spate of sci-fi movies screened a fearsome atomic future. The Air Force went to the movies with its own scary story, producing the stark, propaganda tale *In Your Defense* that opened with its narrator posing the looming threat:

> One of the most dangerous threats to our nation's security is the possibility of attack by high-speed enemy bombers armed with nuclear weapons. These bombers can strike at supersonic speeds from many directions and altitudes to confuse our defense and delay the dispatch of interceptor weapons. In a mass raid, high-speed bombers could be in on us before we determine their tracks. And then it would be too late to act. We cannot afford to take that chance.

This bright boys' project would rapidly grow—seemingly exponentially—as the winds of world events swirled tensely around the brick enclave on Massachusetts Avenue. The idea of how best to engineer real-time command and control into reality began to dominate the huge computer full time.

In September of 1948, the bright boys' youthful leaders, Jay Forrester and Robert Everett, together with two of their mates, Harris Fahnestock and Robert Nelson, put out a blockbuster report called "Forecast for Military Systems using Electronic Digital Computers." [11] It was a two-by-three foot foldout page on which was a 15-year forecast (1948–1963) of computers in the military, covering guided missile data reduction, cryptography, high-speed computer networks, interception networks, air-traffic control, industrial process control, simulation and training, and logistics. The implications of this high-tech roadmap went far beyond the military. It reached far into the future, far beyond what most thought capable of ever emerging from the technology of the late 1940s. It read more like a splashy spread of far-off predictions from an issue of *Popular Science* than serious ideas from serious engineers. In 1948, it was met with incredulity and was completely overlooked. By 1958, it was gospel. Today, it's the way of the world: Information Technology.