UNIT TWO: THE MAINFRAME COMPUTER

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13 William H. Whyte Jr., **The Organization Man** (Garden City, NY: Doubleday & Company, 1956), 231-38. 36

14 Tedlow, **The Watson Dynasty**, 210-13....................40

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Unit Two: The Mainframe Computer

Introduction

Today's laptop and desktop computers are based on the so-called mainframe electronic computers that were developed in the mid-twentieth century for defense and business. While originally filling an entire room, these behemoths nevertheless paved the way for integrating the key elements of personal computers – memories, processors, programs, and outputs.

Before the mainframe computers were developed, rapid processing of multiple data – in Social Security records, in the U.S. Census, in the permutations of insurance claims – was handled by electro-mechanical punch-card machines. World War II accelerated the introduction of electronic systems, using thousands of vacuum tubes. The Cold War demanded computer systems that could work a thousand times faster than the first mainframe systems so as to calculate in "real time" the trajectories and speed of potential air attacks picked up by radar.

So the mainframe was initially a child of the defense industry, but a number of the innovations that made them useful in business, too, were the product of private companies, especially IBM (short for International Business Machines). The founder of the company, Tom Watson Sr., built IBM on the basis of supplying and servicing punch-card data processing machines. It was his son, Tom Watson Jr., who abandoned the punch-card systems because he saw huge opportunities in appropriating and adapting the electronic computer to business needs.

A graduate of Brown University, where he had been a mediocre student, Watson Jr. went to work for IBM and proved himself a capable salesman, but he was more the café society playboy than an ambitious businessman. He matured during World War II, flying military transports for the army, and then returned to the company. He soon wanted to change it, particularly by bringing it into the age of electronic computing, but his relationship with his father was marked by deep-seated tensions, and his eagerness to take charge ran afoul of Watson Sr.'s determination not to be usurped. Eventually, the son won out. His story provides a compelling case of what it takes for innovation to flourish in the environment of a giant corporation.

IBM's Entry into Mainframe Computers

Since World War II, a great deal of innovation in high technology has been carried out in an environment where the federal government has been a major presence, largely because of the needs of national defense. Tom Watson Jr. later remarked that "it was the Cold War that helped IBM make itself the king of the computer business." To be sure, the company could and did make use of the technologies of electronic computing that were developed under military sponsorship, but IBM also flourished because of its farsightedness, Watson Jr.'s managerial skills, and willingness to take risks in order to best its formidable competitors such as Remington Rand. In 1953, adapting and then innovating beyond defense-oriented computers, the company brought out its first business-oriented mainframe machine. By the mid-1950s, IBM was capturing a sizable share of the worldwide computer market, its machines serving multiple data-processing purposes that ranged from the management of giant corporations to the facilitation of speedy and reliable airline reservations.

1 Pauline Maier et al., Inventing America: A History of the United States (New York: W.W. Norton, 2nd edition, 2006), 799-800, 829.

Several historians here provide an overview of the advent of electronic computers and IBM's role in their development.

Mainframe electronic computers were the offspring of research and development for national defense. Originating during World War II, such computers were born from the desire of some scientists and engineers to find a means to calculate artillery-firing tables (optimal aiming settings for guns under different conditions of wind and temperature) better than using hundreds of people to do the necessary arithmetic with hand-operated adding machines. The first electronic computer, called ENIAC (for "Electronic Numerical Integrator And Computer") and completed near the end of 1945, was devised under a military contract at the University of Pennsylvania by J. Presper Eckert, a twenty-four-year-old electronics engineer, and John W. Mauchly, a young physicist. The computer used 18,000 vacuum tubes and could perform 5,000 operations per second. Immediately exploited to do a complicated nuclear-weapons calculation that would have taken one person 100 years at a desk calculator, it finished the job in six weeks.

ENIAC excited an interest in computers on the part of John von Neumann, a brilliant mathematical physicist and prewar refugee from Hungary. In June 1945, von Neumann had published a report laying out what came to be the basic constituents of an electronic computer (units for processing, program, input, and output). ENIAC lacked crucial elements in this design—for example, a capacious physical memory and an operating program—but during the next few years, several projects aimed to develop electronic computers containing all the von Neumann elements, thus laying the foundations of the American computer industry. All were spurred ahead by the engine of national security, through direct military support or military assistance to civilian sponsoring agencies, or by the market created for computers by military contractors eager to employ them in R&D for aeronautics and rockets.

The Korean War prompted a speed-up in the development of computers by both IBM and the Atomic Energy Commission. IBM soon brought out a reliable workhorse that defense contractors could use for scientific computing while other firms further developed computers, responding to demand for them in the government as well as in defense-related areas of the commercial market. . . . The air force, however, felt the need for a high-speed computer that would respond to inputs of information as they were being generated—that would operate, as computer experts liked to say, in “real time.” As a result of the Soviet acquisition of the atomic bomb, the air force wanted to construct a national air warning and defense system across North America, with real-time computers that would detect a Soviet airborne nuclear attack against the United States over the North Pole. An effort to develop such a computer—it was called “Whirlwind”—was under way at MIT, and the air force stepped in with handsome support for it.

….a national air warning and defense system across North America, with real-time computers that would detect a Soviet airborne nuclear attack against the United States.

The project’s prime mover was Jay Forrester, an electrical engineer in his early thirties. . . . Whirlwind needed a memory that was far more capacious and readily accessible than any yet devised. Forrester conceived the idea of forging the necessary memory from small magnetizable cores, each capable of rapidly storing and returning coded information. By 1953, the Whirlwind computer was operating successfully with a magnetic core memory, which eventually became an industry standard.

During the 1950s, defense contractors devised additional computer technologies for the early airborne warning system, including printed circuits (the forerunner of the microchip) and sophisticated software—notably, Fortran and Cobol, used for business analyses. Several companies exploited these technologies for the business market, but none so effectively as IBM, which achieved dramatic commercial success in 1953 with its first business-oriented mainframe computer. In 1955, IBM appropriated Forrester’s innovation to produce the first commercial machine with magnetic core memory, a behemoth weighing 250 tons, firing 49,000 vacuum tubes, and, like all powerful computers of the day, occupying a large room. By 1960, some 5,000 computers had been delivered in the United States and another 2,000 elsewhere in the world, with IBM's products capturing an increasing share of the market.

2 Nicholas Carr, The Big Switch: Rewiring the World, From Edison to Google (New York: W.W. Norton, 2008), 48-51.

Carr, a seasoned writer on technology, describes the increasing penetration of business by electronic computers.

Although it now seems inevitable that the computer would become the mainstay of modern business, there was originally much skepticism about the machine's usefulness. When the first true commercial computer, the UNIVAC, was being built in the 1940s, few people believed it had much of a future in the corporate world. At the time, it was hard to imagine that many companies would have a need for the kind of intensive mathematical calculations that an electronic computer could churn out. The old punch-card tabulators seemed more than sufficient for handling transactions and keeping accounts. Howard Aiken, a distinguished Harvard mathematician and a member of the US government's National Research Council, dismissed as "foolishness" the idea that there would be a big market for computers. He believed that the country would need no more than a half dozen of them, mainly for military and scientific research. Even Thomas Watson is reputed to have said, in 1943, "I think there is a world market for about five computers."

But the designers of the UNIVAC, two University of Pennsylvania professors named J. Presper Eckert and John Mauchly, saw things differently. They realized that because an electronic computer would be able to store its operating instructions in its own memory, it could be programmed to perform many functions. It wouldn't just be a glorified calculator, limited to preset mathematical routines. It would become a general purpose technology, a machine-of-all-trades, that companies could apply not just to everyday accounting chores but to innumerable managerial and analytical tasks. In a 1948 memo, Mauchly listed nearly two dozen companies, government agencies, and universities that he believed would be able to put the UNIVAC to good use. As it turned out, the market proved a good deal larger than even he expected.

Leading the way in adopting the powerful new machines was, once again, the Census Bureau. On March 31, 1951, it purchased the first UNIVAC, installing it a year later in its headquarters in Washington DC. By the end of 1954, Eckert and Mauchly's computers were running in the offices of ten private corporations, including General

Electric, US Steel, Du Pont, Metropolitan Life, Westinghouse, and Consolidated Edison, the descendant of Thomas Edison's Edison Electric Illuminating Company. UNIVACs performed all the jobs that punch-card systems did—billing, payroll management, cost accounting—but they were also used for more complicated tasks like sales forecasting, factory scheduling, and inventory management. In short order, skepticism about the role of computers in business gave way to rampant enthusiasm. "The Utopia of automatic production is inherently plausible," the Harvard Business Review proclaimed in the summer of 1954.

"The Utopia of automatic production is inherently plausible"

The enthusiasm spread to the manufacturers of business machines, who saw in computing an expansive and lucrative new market. Soon after the UNIVAC appeared, IBM introduced its own line of mainframe computers, the 701 series, and by 1960 Honeywell, General Electric, RCA, NCR, Burroughs, and AT&T's Western Electric division were all in competition to sell computer gear. An entirely new industry — software programming — also began to take shape. About forty small software companies, with names like Computer Sciences Corporation, Computer Usage Company, and Computer Applications Inc., were founded during the late 1950s to write programs for mainframes.

It wasn't long before businesses were competing not only on the quality of their products but on the capabilities of their hardware and software. Once one company introduced a new system to automate an activity, other companies, fearful of being put at a disadvantage, followed suit. The first battles in what would become a worldwide information-technology arms race took place in the airline business. In 1959, Cyrus Rowlett Smith, the president of American Airlines, launched an ambitious project to build a system that would automate the making of flight reservations and the issuing of tickets, two labor-intensive processes that lay at the heart of the business. Built by 200 technicians over the course of more than five years, the system, called SABRE, incorporated two of IBM's most powerful mainframe computers as well as sixteen data-storage devices and more than 1,000 terminals for ticket agents. In addition to assembling the hardware, the project entailed the writing of a million lines of software code. When the system went into full operation at the end of 1965, it was able to process 40,000 reservations and 20,000 ticket sales a day—an astonishing feat at the time.

SABRE provided as great an advantage to American Airlines as Burden's waterwheel had provided to his ironworks. American was able to operate with fewer employees and higher productivity than other airlines, which continued to process reservations by hand. It also enjoyed big benefits in customer service, as it was able to respond to travelers' requests and inquiries far more quickly than its rivals could. It gained an intelligence edge as well, as it could monitor demand for different routes and adjust ticket prices with great precision. Building and running computer systems had become as important to the success of American Airlines as flying planes and pampering passengers. In the years that followed, all the other major airlines, including Pan American, Delta, and United, built similar systems. They saw that they had no choice if they wanted to remain competitive. Not surprisingly, they found eager partners in computer vendors like IBM, Sperry Rand, and Burroughs, which earned big profits by replicating similar systems in one company after another.

Bank of America initiated a similar cycle of copycat investments in the banking industry when, in 1960, it unveiled its groundbreaking Electronic Recording Machine Accounting computer in a televised extravaganza hosted by Ronald Reagan. Within two years, the bank had thirty-two ERMA computers up and running, processing nearly five million checking and savings accounts that formerly had to be updated manually. The computers' ability to handle transactions with unprecedented speed and accuracy forced all major financial institutions to follow in Bank of America's footsteps. The same phenomenon was soon playing out in every other industry, as companies matched one another's investments in the latest computer gear.

3 Richard S. Tedlow, The Watson Dynasty: The Fiery Reign and Troubled Legacy of IBM's Founding Father and Son (New York: Harper Business, 2003), 159-165.

Tedlow details the rivalry between Watson Jr. and Watson Sr. and how it affected the management of the company.

IBM's world headquarters in 1947 were located at 590 Madison Avenue in Manhattan. Dad's office was on the seventeenth floor. Junior's was on the sixteenth. Whenever Dad wanted to see his son, he would press a buzzer. Young Tom would climb up the flight of stairs that separated them without knowing why he was being summoned. It could be anything from "Son, I want you to meet Mr. Alfred P. Sloan" to "Tom, I'm really dissatisfied with the way things are going west of the Mississippi." Young Tom now found himself both working for and competing against a man by whom he never felt sufficiently loved.

"Fight" is the word. Not "disagreement." These two men fought; and, as Watson Jr. put it, their fights were "savage, primal, and unstoppable."

These two men began to fight. They fought about all aspects of the business. These fights were brutal and awful. The company was changing. The customers were changing. The technology which IBM's products had to embody was changing faster than ever. The threat to the business posed by the antitrust laws was increasing. Everything, in short, was changing; and every change was an opportunity for a fight. "Fight" is the word. Not "disagreement." These two men fought; and, as Watson Jr. put it, their fights were "savage, primal, and unstoppable." . . .

What caused these fights? Here are young Tom's views: "Dad was constantly trying to change me, and I was trying to change him. I wanted an easy old-shoe pal and he couldn't be that. He'd have liked me to be more pliant and defy him less. Each of us wanted something the other couldn't give."

There is probably some truth here. There are other reasons as well. We can never know the whole story because this account has been based on Junior's recollections. Senior never set down his version of events. Even if he'd had the opportunity, one doubts he would have been willing or able to do so. . . . This is, moreover, not only the story of interpersonal conflict. I am convinced the relationship between these two men exercised a significant influence on the development of IBM.

One reason for these fights is not speculation but is a simple fact. Tom Jr. decided to come to work at IBM after World War II. His expectation was that, fairly quickly, he would become the chief executive officer. Tom had worked for his father in the late 1930s, between his "graduation" from Brown and his enlistment in the National Guard; but there is no record of such fights at that time. That is because young Tom had very little ambition at the company then. He blew it off, flying planes and nightclubbing. After the war, he wanted to run the place. He had, he said in one of those bursts of ignorance about himself which accompany the genuine insight in his autobiography, "no illusions about becoming Dad's equal." His ambition was, in reality, boundless.

Dad did not greet the idea of being superseded by his son with unmixed joy. As the 1940s turned into the 1950s, Junior was taking on more responsibility for the operation of the firm. He was becoming more prominent and receiving more publicity. It was he, not Dad, who adorned the cover of Time magazine's March 28, 1955, issue. He was identified as "IBM's Thomas J. Watson Jr." Dad never made the cover of Time. Was he proud of his son? "He didn't talk to me about the article at all," reported Junior. "He never said, 'Great Going!' and I never brought it up." Even at the age of eighty-one, Dad was in no hurry to be known merely as the father of a new man of men. . . .

To be sure, Tom was competitive with people his own age. He was competitive with everybody. But he remained competitive with his father much longer than was healthy. Not long after his father died in 1956, when at last there was only one Thomas J. Watson at IBM, Watson said of his father, "I still needed him emotionally." At the time, Watson was forty-two years old. Needing his father did not make Watson a problematic figure. It was rather what he needed his father for. There would be plenty of fighting and shouting during Watson's tenure as IBM's CEO from 1956 to 1971. But the feeling of being intensely alive and in touch with something within himself that Watson achieved when he and his father were exchanging primal screams ended when his father died. Something within Watson would never be quite worked through. After 1956, he competed with the memory of his father.

During the nine years that the Watsons were running the company at the same time—it could hardly be said that they were working as a team—the impact of both their strengths and shortcomings was evident in the firm. . . .

The son was the future. However, the father had gotten into the habit of not dying. As long as he was around, executives found themselves having to make choices between the two. The older group of executives, who had been with IBM for years, clustered around Dad. Junior found these people to be mere courtiers and looked forward to their disappearance. Dad was not necessarily enthusiastic about Junior's favorites either.

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What did this split between the two Watsons mean to the people at IBM? Here is an example. Young Tom became executive vice president in 1949. He began a drumbeat of complaints to his father that IBM's engineering research was second-rate. The Engineering Department was "a source of the old man's pride," and attacks on it would not go unanswered. At one point during such a "discussion," Dad summoned the vice president of engineering. This gentleman appeared almost immediately, and he could not have been very happy with what he confronted. Dad and Junior were having another one of their arguments, and somehow he had gotten involved. "My son tells me," said Senior, "that we don't have any kind of research organization. Is that true?"

Imagine yourself in the vice president's position. The odds are that you were promoted to your present position by Watson Sr. It is also likely that prior to Senior's asking the question at that moment, you knew that he and his son had been arguing about you and your department. How would you answer this question?

The vice president thought a while. He wasn't being glib. He said . . . (Permit me once again to ask you, the reader, to pause, to ask you not to be "glib," and to think of how you would answer that question at that moment in that circumstance.) Here is what the vice president said, "We have the finest research organization in the world."

Here was young Tom's observation on that statement:

> That was the end of him as far as I was concerned. All businessmen get asked a question like that sometime in their lives. They either answer it with courage and get fired or promoted, or they answer like a patsy. He'd just made a major mistake, because Dad wasn't going to live very long and I was never going to want the vice president around me again.

4 Thomas J. Watson Jr. and Peter Petre, Father, Son & Co.: My Life at IBM and Beyond (New York: Bantam Books, 2000), 227-33.

Watson recalls how acutely he felt competitive threats from other computer companies and what he did about it by drawing on new technologies.

One day in the early 1950s I stopped off in Washington to change planes and Red LaMotte, who was then in charge of our Washington office, came to see me at the airport. "Tommy," he said in his casual way, "the guys at Remington Rand have one of those UNIVAC machines at the Census Bureau now, and soon they'll have another. People are excited about it. They've shoved a couple of our tabulators off to the side to make room." I knew all about the UNIVAC, of course, but the Census Bureau was where punch-card machines got their start back in the 1880s, and it had always been IBM's backyard. I thought, "My God, here we are trying to build Defense Calculators, while UNIVAC is smart enough to start taking all the civilian business away!" I was terrified.

I came back to New York in the late afternoon and called a meeting that stretched long into the night. There wasn't a single solitary soul in IBM who grasped even a hundredth of the potential the computer had. We couldn't visualize it. But the one thing we could understand was that we were losing business. Some of our engineers already had a fledgling effort under way to design a computer for commercial applications. We decided to turn this into a major push to counter UNIVAC. Two and a half years later this product would finally come out as the IBM 702, but the name it had while it was still in the lab was the Tape Processing Machine. It was obvious to everyone that we were finally making major strides away from my father's beloved punch-cards.

Customers wanted computers so badly that we could double the price and still not drive people away.

Now we had two major computer projects running side by side. We had teams of engineers working three shifts, around the clock, and every Monday morning I'd ignore all my other responsibilities until I'd spent a few hours with the project managers and pressed them on how we were doing. People at IBM invented the term "panic mode" to describe the way we worked: there were moments when I thought we were all on board the Titanic. One morning in 1952 McDowell came to me with a new analysis of what the Defense Calculator was going to cost. "You're not going to like this," he said. It turned out that the price we'd been quoting to customers was too low—by half. The machine we thought would cost $8,000 a month was actually going to cost somewhere between $12,000 and $18,000. We had no choice but to go around and let the customers know. To my total amazement, we managed to hang on to as many orders as we'd started with. That was when I felt a real Eureka! Clearly we'd tapped a new and powerful source of demand. Customers wanted computers so badly that we could double the price and still not drive people away.

We knew UNIVAC was years ahead of us. Worse still, Remington Rand seemed to be making all the right moves. On election night 1952, as Dwight Eisenhower was beating Adlai Stevenson, a UNIVAC appeared on CBS. The network had agreed to use the computer for projecting election results. So millions of people were introduced to the UNIVAC by Edward R. Murrow, Eric Sevareid, and Walter Cronkite, who called it "that marvelous electronic brain." It performed flawlessly—so well that the people running it didn't believe what it told them. All the pre-election polls had predicted a close race, but on the basis of a tiny fraction of the returns, the UNIVAC said Eisenhower was going to win by a substantial margin. That made the Remington Rand people so nervous that they disconnected a part of the UNIVAC'S memory to bring its prediction in line with the polls. But the machine was right, and at the end of the evening an engineer came on screen and sheepishly admitted what he'd done. Remington Rand's machine became so famous that when our first computer came out, we found it being referred to as "IBM's UNIVAC."

The Defense Calculator, or the IBM 701 as it was officially called, came off the production line in December 1952. . . . [IBM unveiled the machine the following April to an audience of distinguished scientists and businessmen.] Our visitors were impressed with the new computer, and newspapers all over the country picked up the story. But the noisiest reaction came from the big customers who had been pushing us for years to start building computers. Now that we'd delivered the 701 for scientific use, they wanted us to announce the computer we were designing for businesses. "Stop fiddling around," said my Time Inc. friend Roy Larsen. "Show us what you've got so we can decide whether to buy a UNIVAC." Even at this late date some of our punch-card executives were still insisting that computers would never be economical, but the fact that we had customers waiting helped me to override their objections. We announced the IBM 702 in September, and in the space of eight months we had orders for fifty of them.

Meanwhile I turned my attention to the most important sale of my career. In the 1930s Dad had been able to boost IBM into the top echelon of corporations by supplying punch-card machines for Social Security and the New Deal. There were no such massive social programs under Truman or Eisenhower for us to tap into. It was the Cold War that helped IBM make itself the king of the computer business. After the Russians exploded their first atom bomb in 1949, the Air Force decided that America needed a sophisticated air defense system. They also decided this should incorporate computers —a very bold idea for the time, because computers were still little more than experiments. The government gave a contract to MIT, and some of the country's best engineers there drew up plans for a vast computer-and-radar network which was supposed to blanket the United States, operate around the clock, and calculate the location, course, and speed of any incoming bomber. The military name for this system was Semi-Automatic Ground Environment, or SAGE. . . .

The MIT engineer responsible for procuring the SAGE computers was Jay Forrester, an austere man about my age who was driven by a belief that computers could be made to do more than anyone thought. In the summer of 1952 he was traveling around the industry visiting the five companies in the running —RCA, Raytheon, Remington Rand, Sylvania, and IBM—and everybody was pulling out the stops. RCA and Sylvania trotted him through their huge vacuum tube factories that were supplying everyone in the industry. Remington Rand showed off the UNIVAC and brought in as their spokesman the famous general, Leslie Groves. During the war Groves had been the boss of the Manhattan Project, which built the atom bomb.

I tried not to worry about Groves or the other competitors; I just let IBM speak for itself. I took Forrester to see our plants and introduced him to our most gifted people. He was under extreme pressure to get the system into production as soon as possible, and I think what impressed him was the fact that we were already building computers in a factory. We won a small contract for the first stage of the project, to build prototype computers in conjunction with MIT.

To make SAGE possible the computers had to work in a way computers had never worked before. In those days computing was typically done in what was called batch mode. This meant that you would collect your data first, feed it into the machine second, then sit back for a little while until the answer came out. You could think of the batch processor as a high diver at a circus—each performance involves a lengthy drum roll in preparation, a very fast dive, and then a splash. But the SAGE system was supposed to keep track of a large air defense picture that was changing every instant. That meant it had to take a constant stream of new radar information and digest it continually in what is called "real time." So a SAGE computer was more like a juggler who has to keep a half dozen balls in the air, constantly throwing aside old balls as his assistants toss him new ones from every direction. As if real-time computing were not enough of a technical challenge, the Air Force also wanted the system to be absolutely reliable. In those days it was considered an accomplishment if someone could build a computer that would work a full eight-hour day without failing. But SAGE was supposed to operate flawlessly around the clock, year in and year out.

When Russia exploded its first hydrogen bomb in the summer of 1953, the need to finish SAGE became even more urgent. We took many of our top engineers off our other computers and put them to work with Forrester and his men. A year after we started we had seven hundred people on the SAGE project, and it took only fourteen months to design and build a prototype that would do the job. It was a monster of a machine, far larger than any computer that had ever been produced. The Air Force called it the AN/FSQ7—or Q7 for short—and it had fifty thousand vacuum tubes and dozens of cabinets spread out across a large warehouse. . . .

…there were times in our dealings with MIT when I thought we'd blown it.

Although we'd built a successful prototype, we weren't guaranteed the next stage of the project. The lion's share of SAGE—the contract to manufacture and service the dozens of computers that would make up the actual system—was still up for grabs. I thought it was absolutely essential to IBM's future that we win it. The company that built those computers was going to be way ahead of the game, because it would learn the secrets of mass production. We had the inside track because we'd built the prototype, but there were times in our dealings with MIT when I thought we'd blown it.

Forrester was a genius at computer hardware, but he didn't appreciate how hard it is to set up a reliable production process. . . . I was worried he'd shift SAGE somewhere else. I worked harder to win that contract than I worked for any other sale in my life. I was constantly making trips up to MIT. Forrester hemmed and hawed, but I finally told him that if he promised me the production assignment, I would build him a factory without waiting for a contract. "Give me your handshake, and we'll start on the plant this week," I said. I knew he was afraid that he might have to wait a long time for the paperwork from the Air Force. So he told me to go ahead.

Within a couple of years we had thousands of people working on SAGE and those big Q7s were in operation all over the continent. We built forty-eight in all. . . . SAGE was celebrated as one of the great technical achievements of its day. But although the system worked fine, the arms race made it obsolete before it was even finished. It could guard against attacks by bombers, but not missiles, so when the Russians launched Sputnik in 1958, SAGE became *passé*. . . . [But] it gave IBM the giant boost I was after. Until the late '50s, SAGE accounted for almost half our total computer sales. We made very little money on the project, in keeping with the policy against war profiteering laid down by Dad. But it enabled us to build highly automated factories ahead of anybody else, and to train thousands of new workers in electronics.

5 Steve Usselman, "Learning the Hard Way: IBM and the Sources of Innovation in Early Computing," in Naomi Lamoreaux and Kenneth Sokoloff, eds. Financing Innovation in the United States, 1870 to the Present (Cambridge: MIT Press, 2007), 317-325.

Usselman emphasizes that, while the federal government paved the way for electronic computing, IBM did a great deal to adapt mainframe computers to business needs.

Accepted wisdom in current scholarship holds that modern computing is a product of massive public investment. Virtually all histories of computing technology place significant emphasis on the role of government funding in general and on that of military expenditures in particular. . . . My goal is not to dispute fundamentally the proposition that government has exerted a profound influence over computing. Rather, I wish to suggest some ways in which private enterprise and private capital have also figured in the story. In particular, I seek to comprehend how one firm, IBM, contributed to the emergence and refinement of the stored program electronic computer during the two decades from the close of World War II until its production of System/360, a comprehensive line of such machines whose basic architecture would dominate America and world markets for mainframe computing for another two decades or more. . . .

Accounts stressing the importance of government and the military to computer development at IBM typically emphasize two large projects launched at the time of the Korean War. One was the Semi-Automatic Ground Environment (SAGE) system, which deployed twenty-three pairs of massive electronic computers operating in real time to monitor American airspace and deploy anti-aircraft fire in response to potential Soviet invasion. Growing out of Project Whirlwind, a computer development project sponsored by the Air Force and coordinated by MIT scientist Jay Forrester, SAGE offered IBM an opportunity to manufacture electronic circuits in high volume and to deploy and maintain machines built from them and operating in highly demanding circumstances.

The second project was the IBM 701, an advanced programmable computer of standard design intended primarily for use in engineering calculations and other tasks performed by large defense laboratories and military contractors. Its nickname during development—the Defense Calculator—made clear its ties to the military market. During the early 1950s, IBM placed approximately twenty of these machines in the field. No previous computer of such power had been produced in such numbers.

"I knew if you got the SAGE contract," he once told an interviewer, "you got the computer business."

There is no disputing that IBM pursued these military projects in hopes of gaining critical advantages over its competitors in the market for commercial computing. Thomas Watson Jr., who as executive vice president had taken over responsibility for product development and strategy from his CEO father, made this perfectly clear at the time and in later recollections. "I knew if you got the SAGE contract," he once told an interviewer, "you got the computer business."

In diverting his most talented people from ongoing projects aimed at commercial markets, Watson looked to gain experience in electronic component design and manufacture that would soon be transferred into commercial products of more advanced capabilities. Watson closely monitored efforts to build circuits for SAGE using automated equipment for inserting electronic components into printed circuit boards and for wiring and soldering the boards themselves. He toured IBM facilities showing films of the equipment and urging his engineers to make use of them in commercial projects. Watson expressed severe disappointment that Forrester and his MIT colleagues decided against using solid-state transistors, a technology he and others at IBM regularly referred to as an "automation technique" because in their minds it promised above all to drive down the cost of building electronic circuits. SAGE did, however, take advantage of another mass-produced solid-state component when it used arrays of small magnetic doughnuts for its core memories. The doughnuts were formed using pill-pressing equipment modified by IBM mechanics and were wired with inserters also designed by those skilled holdovers from the firm's heyday as a manufacturer of electro-mechanical machines. Such arrays remained the basic memory technology of IBM computers through System/360, until the advent of silicon chip memory in the early 1970s.

When all eighteen customers agreed to the hefty price increase, I knew we had the bull by the horns."

Watson also intended for the 701 to serve as a learning exercise that would yield benefits for the commercial sector. IBM conducted a parallel development project, the 702 Business Calculator, that would borrow techniques developed for the Defense Calculator and apply them to a machine targeted at large commercial customers such as insurance companies and banks. When development costs for the 701 soared, effectively doubling the promised monthly rental charge, Watson decided against declaring the project a loss leader and absorbing the costs as the price of learning. He wanted the development engineers and the sales and maintenance force to operate within the constraints imposed by a balance sheet showing true expenses and profits, as they would have to do in the commercial sector. When all eighteen customers agreed to the hefty price increase, Watson later recalled, "I knew we had the bull by the horns."

The record, then, seems quite clear. IBM not only benefited from public investment in the form of military contracts; it consciously viewed these defense projects as springboards to commercial dominance. The fact that System/360 incorporated magnetic core memories and electronic circuits built using descendants of the assembly equipment developed for SAGE appears only to confirm the overriding influence of government on early computing. Add in that System/360 also used silicon transistors, a technology whose development was supported in large measure by military projects, and that influence looms still larger.

In reality, however, the story is not quite so straightforward. Probing more deeply into events at IBM, several complicating features come to light. First, efforts to integrate electronics into advanced calculating machines were underway at IBM even before the advent of stored program computing during World War II. Second, in the years immediately following the War, as its fortunes soared from returns on investment in its traditional product line, IBM had embarked on several development projects aimed at bringing electronic computing to the commercial sector; Watson's play for military contracts at the start of the Korean conflict diverted vital resources and temporarily derailed those commercial ventures. Third, IBM won the military contracts because it had established capabilities in marketing, manufacturing, and maintenance that government and the military recognized as lacking in other potential contractors. The defense programs thus served as a vehicle through which essential knowledge and practices accumulated in the commercial sector were transferred to the emergent field of electronic computing. Fourth, techniques mastered for SAGE and the 701 did not move easily into commercial operations, and efforts to force the transfer often proved highly disruptive; much of the critical learning at IBM during the 1950s actually occurred in the course of producing more modest machines for the commercial market, which generated earnings that IBM invested in subsequent developments in electronics. Fifth, when circuitry built from solid-state components assembled by highly automated processes did make their way into IBM commercial computers, demands of subsequent military contracts threatened to draw circuit designers away from the objectives of simplicity and low cost that were critical for success in the commercial sector. In tying silicon technology to these more modest objectives and mobilizing enormous amounts of financial resources toward the effort, IBM helped push the emergent field in new directions that would yield enormous benefits.

LAYING A FOUNDATION

Before examining these propositions in more detail, it will be useful to become familiar with some critically important features of IBM's business practices during this period. Most of these were inherited from methods instilled by the elder Thomas Watson, who took over the firm in the early teens after a long apprenticeship at John Patterson's National Cash Register Company. IBM thrived under Watson by cultivating an integrated organization aimed at providing specialized data processing services to businesses and other large organizations. The strategy hinged on IBM's dominance in accounting machinery built from complex assemblies of mechanical gears, chains, springs, and ratchets and a smattering of relays and other electromechanical devices. The machines read data stored on punched cards, performed any of a variety of calculations on it, printed the results in various formats, and stored the results, again on cards. Customers leased the equipment from IBM on a monthly basis and purchased cards from IBM, which until a consent decree in 1936 had exclusive rights to the card market. Field engineers and service representatives from IBM spent considerable time with customers, maintaining the machines, devising new ways to manipulate and present data, and installing new components and other refinements that made these novelties possible.

These arrangements lent an enviable financial stability to IBM. As observers such as historian Robert Sobel have noted, IBM had many attributes of a bank or insurance company. While those institutions converted the funds they raised into loans or term-life policies, IBM turned its capital into leasing agreements. Equipment placed with customers under these agreements constituted an installed base of capital that generated revenue at fairly predictable levels. . . .

This mode of doing business enabled IBM to pursue innovation in a highly deliberate manner. The last thing IBM wanted was to introduce change so rapidly as to render its installed base obsolete. The elder Watson steered clear of the speculative investment in research that came to characterize firms such as RCA, Du Pont, and Kodak. At IBM, the vast majority of research and development expenditures occurred in the course of particular product development efforts. Many of those efforts, moreover, took the form of ongoing refinement and modification rather than breakthrough new designs. IBM honed sophisticated routines for linking field engineers at customer sites with designers and manufacturers working at its facilities in isolated Endicott, New York.

Responsibility for introducing entirely new machines or thoroughly updated models of old ones fell to a group known variously as Future Sales or Product Planning. Blending elements of sales, engineering, finance, and market forecasting, this group monitored ongoing innovation occurring at customer sites and decided when to incorporate new functions and capabilities into regular commercial products to be built in volume and leased at a standard price. Product planners set specifications for price and performance and then turned to a crack team of mechanical inventors in the design laboratory at Endicott. Often Watson set teams in this design shop against one another in a race to come up with a suitable machine. The victorious team then turned the product over to a group known as manufacturing engineering, which looked for ways to build the designs economically in volume. A manager from Product Planning, generally reporting directly to Watson, supervised the entire process. It was his job to get the product out the door and generating rental income. The task was demanding, for IBM expected each major new product development effort of this sort to pay for itself in five years. Delays ate into the projected revenue stream and pushed back the day when all associated costs would be written off and the installed machines would pump pure profit into IBM.

This style of innovation, which tied research and development to particular product programs that were expected to generate revenues sufficient to cover all costs, persisted long into the 1950s as IBM attempted first to introduce electronics into the world of data processing and then to master the emerging world of solid-state components and circuitry. Both Watsons were reluctant to spend money on centralized research that was divorced from the sort of accountability provided by product development programs aimed at commercial markets. Learning at IBM throughout the early computer era was thus tightly joined with established functions and routines operating across the firm and with the expanding commercial market for data processing that IBM already dominated. This strategy, largely the residue of inherited habit and financial conservatism, proved fortuitous. The sort of integrated learning and technical compromise it fostered turned out to be highly suitable for the emergent new field of electronic computing.

6 Watson and Petre, Father, Son & Co., 241-46, 248.

Here Tom Watson Jr. recalls how IBM, exploiting new technologies, then built a whole business infrastructure to produce and sell machines that would serve vastly different businesses. Under Watson, IBM institutionalized innovation by establishing its own in-house research laboratory on the cutting edge of science. For innovation to flourish, there must be leadership.

> By the mid-'50s "computer" was becoming a magic word as popular as vitamins. Top executives rightly believed that the companies of the future were going to be computer run. Board chairmen would say, "We've got to get a computer!" Everybody wanted one, even though precisely how to use the machines was still a mystery. It became the conventional wisdom that management ran a bigger risk by waiting to computerize than by taking the plunge.
>
> If Remington Rand had put their money and hearts behind the UNIVAC right at the start, maybe they'd have been in Time magazine instead of us. But nobody at the top of the company had a vision of what computers might mean. Jim Rand was more of a conglomerateur. While Dad was saying "Shoemaker, stick to your last," Rand's company was selling everything including office equipment, electric shavers, autopilots, and farm machines. Rand wouldn't even let Eckert and Mauchly use his punch-card salesmen to market computers—he said it would cost too much. Instead things were set up so that if a new UNIVAC displaced Remington Rand punch-card equipment, the punch-card salesman lost commissions.
>
> At IBM there was never any question—we put the whole weight of our sales force behind our computers as soon as they were announced. At first our salesmen knew almost nothing about them, of course, so we made sure that senior executives and the engineers who did know were available to help them sell. Months before the machines were ready for delivery we hired dozens of graduate mathematicians and physicists and engineers to help customers decide how they might use the computers when the machines arrived. To spread knowledge of the new field, we held seminars in Poughkeepsie for our customers and salesmen both.

We consistently outsold people who had better technology because we knew how to put the story before the customer, how to install the machines successfully, and how to hang on to customers once we had them.

In the history of IBM, technological innovation often wasn't the thing that made us successful. Unhappily there were many times when we came in second. But technology turned out to be less important than sales and distribution methods. Starting with UNIVAC, we consistently outsold people who had better technology because we knew how to put the story before the customer, how to install the machines successfully, and how to hang on to customers once we had them. The secret of our sales approach was the same thing that made Dad so successful in punch-cards: systems knowledge. That was where IBM had its monopoly. No competitors ever paid enough attention to it, not even the people at Remington Rand, who should have known better because they were in the punch-card business too.

By the spring of 1954, IBM and UNIVAC were running a close horse race. In terms of computers actually installed, Remington Rand still had the lead by about twenty to fifteen. But our salesmen, racing far ahead of our factories and engineers, had piled up enough orders for us to outdistance Remington Rand four times over. All we had to do now was deliver. Our bestseller was the new computer we'd announced for accounting applications, the 702. We had orders for fifty of these, which we were getting ready to build in a three-year production run starting that fall. The program was on schedule, but so much was riding on the 702 that everybody involved was extremely jumpy. Even Dad felt the tension and worried that other companies were going to steal the business away. "At the rate we are going we will never fill those orders," he would scold.

Bringing out the 702 on time meant that all of IBM's departments—product planning, engineering, manufacturing, sales —had to cooperate. I didn't assume this would happen automatically—the project was complicated, and there were a lot of punch-card men who would be just as happy to see computers disappear. We could easily trip ourselves up, and I decided we needed somebody in charge of making sure that didn't happen. I chose Vin Learson, who had emerged as one of IBM's best operating executives. He was six feet six inches tall, and his mere presence in a room was enough to get people's attention. The job turned out to be one of the most important assignments in IBM history.

By summer our engineers realized, to their horror, that the 702 was probably not the great UNIVAC-beater we thought. One big problem was the machine's memory. The type of storage circuitry we were using worked faster than the circuitry in the UNIVAC, but it also "forgot" bits of data more often. We could make the 702 perform reliably enough that delivering it to customers wouldn't hurt IBM's reputation, but only by providing laboratory-trained teams of specialists to babysit the machines. Our engineers and production managers weren't sure how to proceed.

Learson turned this quandary into a triumph. His first move was to order a crash redesign of the machine. He took what we'd learned working for the Air Force on SAGE and used it to skip a grade, so to speak, in computer development. The MIT engineers on SAGE had achieved a historic breakthrough in memory technology that involved storing data on arrays of tiny doughnut-shaped magnets called "cores." Core memory was ultra-reliable, and our engineers had been planning to incorporate it in the next generation of IBM's computers, about three years down the road. But Vin told them to jump on it right away. He drove the engineers at such a ferocious pace that in less than six months we'd revamped our entire computer line with core memory. Meanwhile Vin decided that we'd go ahead and manufacture the relatively unreliable 702s, but just for a year as a stopgap. As soon as the newer design could be produced, we'd switch our customers to those and either upgrade or replace the old machines.

In a little over a year we started delivering those redesigned computers. They made the UNIVAC obsolete and we soon left Remington Rand in the dust. By the time the presidential elections rolled around in 1956, we had eighty-seven machines in operation and one hundred ninety on order, against forty-one in operation and forty on order for all other computer-makers. Eisenhower beat Stevenson again, but this time the computers you saw on TV were IBM machines.

Whenever we had superior technology to complement our systems knowledge, our business skyrocketed. That happened when we started delivering a small computer called the 650, in 1954. It was far less powerful than the Defense Calculator, but much cheaper. Competitors like Underwood Typewriter and National Cash Register were racing to build small computers that could be used by ordinary businesses, but the 650 outperformed them all. Over the next several years it enabled us to bring thousands of punch-card customers into the computer age. The 650 rented for about four thousand dollars a month, and was the perfect choice for companies eager to try computing because we designed it to work along with ordinary punch-card equipment. Yet it could do accounting jobs that were beyond punch-cards. For example, life insurance companies used to spend a lot of money calculating premium bills. Depending on age, sex, and other factors, each life insurance customer was supposed to be charged at a different rate, and typically this calculation was done by hand. Clerks would look up the rates in tables and work out the amount due on adding machines. But with the 650, the companies could load their actuarial tables into its memory and the computer did the work. Its ability to handle these bread-and-butter applications made the 650 hot. While our giant, million-dollar 700 series machines got the publicity, the 650 became computing's Model T.

Within five years there was a whole new generation of computer scientists who made it possible for the market to boom.

We played a large role in creating new professions such as programming and systems engineering. As it finally became obvious that we were giving birth to a whole new industry, we discovered that the world wasn't entirely ready for our machines. It was as though we had the airplanes, but no one to fly them and no place to land. Our customers often complained that the most difficult thing about having a computer was hiring somebody who could run it. They'd ask for help, we couldn't provide all those technicians ourselves, and there was not a single university with a computer curriculum. Sometimes we even found ourselves in a position where we had to hold back from taking a customer's order. So I went up to MIT in 1955 and urged them to start training computer scientists. We made a gift of a large computer and the money to run it, and they shared that machine with ten other schools in the Northeast. For the 650, we adapted a very aggressive college discount program that existed for our punch-card machines: you could get 40 percent off for setting up a course in either business data processing or scientific computing, and 60 percent off for setting up courses in both. I put these education policies near the top of the list of IBM's key moves, because within five years there was a whole new generation of computer scientists who made it possible for the market to boom.

Wherever I traveled during those years, I tried to recruit top people for IBM's research and development side. The engineers who were hardest to attract were those graduating from Stanford and Caltech and the University of California—the smart ones never wanted to leave the West Coast sun to come East. So, very early on, we decided to put a laboratory out in San Jose, and I bought a building that had been intended for a supermarket. The man we sent to manage the new lab was Reynold Johnson, one of Dad's self-taught inventors from Endicott. He had started out as a high school teacher in Minnesota and he came to IBM in the 1930s proposing a machine that could automatically read and grade multiple-choice tests for schools. Some executives told him the idea was impractical, but Dad overruled them, put Johnson on the payroll, and let him build his machine. IBM made several million dollars on test scoring equipment, and the method is still used on college admission tests today.

Johnson was delighted at the thought of escaping from the rivalries and pressures of Endicott and directing his own lab. He moved to California, hired three dozen young engineers, and in less than three years presented IBM with an invention that was truly spectacular: the computer disk. It stores data in the form of tiny magnetized spots on its surface, and one problem Johnson faced was how to lay down a coating on the disk that was uniform enough to permit this. I remember the day I saw him demonstrate his solution. He stood in front of a spinning aluminum disk with some magnetic coating in a paper cup, and began pouring it slowly, like a milkshake, onto the disk's center. When the stuff spread out to near the edge, he stopped pouring, and he had a magnetic disk. The machine he invented, which we called the RAMAC, incorp-orated fifty of those disks stacked like records in a jukebox, except that they all were spinning at once. A little arm would move in and out among the disks, extending a recording head over the disk surfaces to pick up the data that were needed. The descendants of Rey Johnson's disks are the main data storage devices in virtually every computer system today, from very large mainframes down to ordinary PCs, and they revolutionized the computer's usefulness. Computer tapes like those used with the Defense Calculator don't work well in applications where a computer has to look up a particular piece of information—to check a customer's bank balance, say, or tell how many seats are still available on a particular airline flight. Without Rey Johnson's disks those applications never would have been practical. To see why, you only need to imagine a music lover who has a collection of both records and tape cassettes. If he wants to play a favorite song on a tape, he has to wait while the tape deck fast-forwards to the proper spot; but with a record, he can move the phonograph needle directly to the right track and hear the music instantly. A computer equipped with a disk homes in on data in much the same way, and the RAMAC made it possible to retrieve information two hundred times as fast as with magnetic tape.

While we were proud of our computers, proud of our disks, and proud of our tape drives, I didn't fool myself into thinking that IBM had much genuine scientific prowess. We were a maker of electromechanical equipment trying to go into a very sophisticated field with almost no background. Because of this I kept working to increase the flow of technical information into IBM. When we first started building computers, for example, we arranged for John von Neumann, the eminent Princeton University computer theorist, to give seminars to our men at Poughkeepsie. Von Neumann was one of the atom bomb pioneers and he practically defined the modern notion of software; I didn't understand his work, but I knew how important he was. From then on we kept a steady stream of experts coming in, and we frequently sent our engineers out to university courses as well.

But it was soon obvious that this wasn't enough, and we began searching for a senior scientist to come and organize a program of pure research within IBM. . . . [He was Emmanuel Piore, a physicist and a former high-ranking government scientist.] Piore gave a jolt to some of our product-development engineers as well. They were like sprin-ters encountering their first marathon runner, and were amazed to see IBM start funding experiments in exotic fields that seemed unlikely to bear fruit for decades, if ever—like superconductors and artificial intelligence. What the engineers thought of as basic research Piore often dismissed as mere long-term product development, and what he called research was so far removed from what the engineers were doing that they saw no reason for it at all. At Piore's urging we doubled the percentage of our revenues devoted to research and development, and much of the additional spending was earmarked for pure science.

COMPUTERS IN THE NEW TECHNOLOGICAL PROSPERITY

The 1950s ushered in an era of affluence that was made possible to no small degree by advances in technology coupled with the policies of the welfare state. An increasing fraction of Americans made their living in white collar jobs, providing and managing services and information. Computers increasingly facilitated their tasks, from the prediction of election results to on-screen processing of airline reservations. Critics of the trend deplored the displacement of workers by electronically controlled machines, what people called "automation." Defenders of the trend called it "progress," but Watson Jr., who was a liberal Democrat and a friend of John F. Kennedy and his family, came to recognize that it cost people jobs and that their plight could not be ignored.

7 Robert Samuelson, The Good Life and Its Discontents: The American Dream in the Age of Entitlement, 1945-1995 (New York: Vintage Books, 1997), 34-37.

Samuelson outlines the pervasiveness of the prosperity of the 1950s. The material well-being of the era was the joint product of the social welfare programs and the consumer technologies of the postwar period, among them Social Security and private pensions, health insurance, the G.I. Bill of Rights, the expansion of higher education, interstate highways, television, jet air travel, air conditioning, automatic washers and dryers, and antibiotics.

If you grew up in the 1950s (as I did), you were a daily witness to the marvels of affluence. There was a seemingly endless array of new gadgets and machines. At home, you watched television. At school, you were vaccinated against polio, until then a dreaded disease. Outside, you could occasionally gaze upward and catch the distant vapor trail of a new jet. You watched in wonder until it vanished. Cars were becoming ever bigger, fancier, and more powerful. Atomic energy seemed to promise an inexhaustible source of cheap energy. No problem seemed beyond our power to assault and conquer. Good times and the ingenuity of American technology: these were not lessons learned, they were experiences absorbed. The presence of so much prosperity impressed almost everyone and had the effect of cultivating a new postwar consciousness.

We began — as never before in American history — to take prosperity for granted.

Certainly, most middle-class children (the core of the postwar baby boom) did. Prosperity was all that they had ever known. Their parents, too, were increasingly convinced because the depth and duration of postwar prosperity seemed to prove that something new (and basically wonderful) had happened. To be sure, there were those inconvenient recessions. But they were trifling compared with the Depression of the 1930s, which, of course, was the comparison that most adults made. . . .

These notions came to full fruition in the 1960s, as the advance of prosperity continued and actually accelerated. All during these years, millions of Americans were moving into more spacious suburban homes, which—though they had their critics—represented a real and much desired improvement for most of their owners. . . .

The movement into new homes with lawns, garages, and privacy was simply a part of the larger mosaic of material progress. The proliferation of new conveniences made ordinary life less demanding and less physically exhausting. As factories grew more automated, they became less punishing on their workers. Indeed, factory automation meant that a rising proportion of Americans found cleaner, safer, and less arduous jobs in offices and stores. By 1970, about 60 percent of the workforce consisted of white-collar or service jobs (managers, administrators, teachers, professionals, sales workers, office workers), up from 39 percent in 1930. . . .

Our growing wealth would, spontaneously or otherwise, overcome other social or personal problems.

Reading between the lines, the drift of things seemed clear. Economic concerns would fade from ordinary worries, and our growing wealth would, spontaneously or otherwise, overcome other social or personal problems. Since its beginnings, for example, America had been a country of vast regional differences and conflicts. These now seemed to be narrowing, as television, new highways, and long-distance telephone service drew the nation — in time, income, and lifestyle — closer together. . . .

8 Maier et al., Inventing America, 828-29.

In this passage, the authors summarize how in the 1950s leading American companies helped fuel the expanding prosperity by becoming more powerful engines of innovation.

The huge investments in military R&D spun off benefits to the civilian economy. For example, in 1959, signifying a leap forward in the aircraft industry, Pan American

World Airways started flying passengers non-stop to Europe with jet-powered Boeing 707 planes, whose engines had been developed for the military, cutting the time for the journey from New York to Paris to 6 hours and 55 minutes, half the time of the fastest piston-engine plane. Taking advantage of the spinoffs, many small firms were founded with the aim of developing the knowledge and technologies into marketable products. They were fueled by the new and burgeoning venture capital industry, individuals and financial firms devoted to investing in pioneering companies.

All the while, many established industrial companies increased their spending on programs of scientific research and development. Those that had not previously invested significantly in R&D had been taught by the mobilization of science during World War II that organized research could produce profitable new technologies. An executive at the Ford Motor Company, which had previously invested little in science, told Henry Ford II that “Ford will not have many ‘firsts’ unless we get a few good thinkers and have a real research department.” In mid-1951, Ford established a scientific laboratory in Dearborn, Michigan.

A number of firms, including those with established R&D programs, also saw in innovation a way to prosper without running afoul of the antitrust laws. The new products that might come from research could lead to company growth through diversification rather than through giantism in single areas of production and competition. This strategy prompted greater postwar investment in R&D at mainstay firms of American high technology, including Du Pont, General Electric, Kodak, AT&T, RCA, and IBM. In response to the creation of the Common Market in Europe in 1957 (a group of nations mutually free of tariff barriers), a number of American firms established research laboratories in Europe, thus laying part of the foundation for globalization.

Between 1945 and 1960 the number of hours required to produce a car dropped by half.

The steel and automobile industries invested heavily in labor-saving technology, so that, for example, between 1945 and 1960 the number of hours required to produce a car dropped by half. During the same period, productivity in manufacturing on the whole increased by 52 percent. Drawing on technical advances that had begun in the 1930s and had been accelerated by military demands during World War II, the chemical industry increasingly found ways to turn petroleum and natural gas—they had replaced coal as its principal natural resource—into a variety of products. Different plastics increasingly replaced glass, leather, wood, steel, aluminum, and paper. New synthetic fibers—notably, polyester and acrylics—increasingly displaced natural cotton and wool in the textiles market, making available clothing that was easier to clean and resistant to shrinkage and wrinkling.

In 1948, a trio of scientists at the Bell Telephone Laboratories had devised the transistor, a technology that would revolutionize electronics (and earn the inventors a Nobel Prize). Picking up on radar-related work during World War II, they discovered that an arrangement of small wires and a semiconducting material could be made to control the flow of energy in electrical circuits. It would thus do the work of vacuum tubes, which were essential to every electronic device from radios to radar; but it was much smaller, consumed much less power, and promised to be more reliable. Although the invention of the transistor was accomplished with the Bell Laboratories' own funds, during the Korean War the military stepped in to speed up its development. By the end of the war, defense contracts had come to support fully half the work, and the military bought almost all the transistors first produced. However, transistors then began entering the commercial market, finding uses in hearing aids, portable radios, and, before long, computers.

9 William Manchester, The Glory and the Dream (Boston: Little, Brown, 1974), 1087-88.

Manchester outlines the ambivalence many Americans felt towards their technology-dependent lives, linking it to the protests of British workers against the technologies of the early industrial revolution. During the 1960s, many people felt that machine society was depriving them of autonomy and dignity. Students rioted over the Vietnam War, identifying technology with militarism, and protested their relegation to punch-card identities by modern university bureaucracies.

Taking their name from a half-witted Leicestershire worker who had attacked a machine a generation earlier, British handcraftsmen thrown out of work by the industrial revolution declared war on shearing frames and power looms in 1811. From a mythical retreat in Sherwood Forest they issued a nonnegotiable demand:

> We will never lay down Arms [till] The House of Commons passes an Act to put down all Machinery hurtful to Commonality, and repeal that to hang Frame Breakers. . . . We petition no more — that won't do — fighting must. Signed by the General of the Army of Redressers

NED LUDD Clerk

Soreheads standing in the way of labor-saving devices have been known as Luddites ever since, and critics of America's increasingly technocratic society during the Johnson years were frequently accused of Luddism. In instances of rioting students this was sometimes justified. Professors' notes were destroyed, equipment was damaged, and a sign plastered on one Cambridge computer accused it of drawing high wages and fringe benefits at the expense of American workmen. That was as absurd as Ned at his most futile, but the case against technocracy was not entirely preposterous. Intelligent men and women were tired of receiving punch-card mail, riding on push-button elevators, standing in check-out lines, reading about a war being judged by body counts, listening to recorded voices over telephones, and being treated during political campaigns as pollster percentages. As Nicholas von Hoffman pointed out, the demonstrating students were rebellious at being "admitted, tested, and flunked by computers." . . .

“In this social process, man himself is being transformed into a part of the total machine."

[The social psychologist] Erich Fromm warned: "A specter is stalking in our midst. . . . It is a new specter: a completely mechanized society . . . directed by computers; and in this social process, man himself is being transformed into a part of the total machine." Millions of Americans by the late 1960s were carrying as many as twenty multiple numbers in their wallets, some indicating their various identities, some necessary for daily business, and all tending to reduce them to random particles — zip codes, area codes, blood types, drivers' licenses, automobile licenses, social security numbers, army serial numbers, and numbers of charge accounts, checking accounts, book club memberships, insurance policies, passports, birth and marriage certificates, mortgages, and Veterans Administration claims. The author of The Beast of Business recommended playing "computer-card roulette" by closing holes with tape, cutting new holes with a razor blade, and exposing the code number to an electromagnet. When a California janitor received a $5,000 check for two weeks' work, everyone cheered except the aeroelasticity investigators, inertial systems engineers, superconductivity research specialists, and digital circuit design specialists — those, in short, whose great age this was.

John Mauchly, the builder of the first U.S. commercial computers, had predicted that "only four or five giant firms will be able to employ these machines usefully." He underestimated his prodigies. There were 1,000 computers in the United States in 1955. In 1960 government engineers suggested that 15,000 might be in use within five years. The time arrived and 25,000 were in use. By 1967 there were 40,000

10 Time, March 28, 1955 – Thomas Watson Jr. on cover
http://img.timeinc.net/time/images/covers/19550328_107.jpg
and cover story "The Brain Builders,"
http://www.time.com/time/magazine/article/0,9171,937187,00.html, excerpts.

As in the era of the Luddites, an essential fear raised by electronic computers was that they put people out of work. Indeed, Watson later recalled that IBM had "sold punch-card machines on the basis of how many clerks they'd replace." In many industries, technological developments had previously destroyed jobs. For example, talking films ended the need for musicians to accompany silent films and automatic telephone switching abolished the requirement for operators to direct calls from one exchange to another. But the benefits of these innovations, notably auditorily expressive films and dial-up calling, were enormous. And while data processors did abolish the need for certain kinds of clerks, they created tens of thousands of new jobs in fields such as computer programming, maintenance, and sales. Here Time magazine reports the apprehensions aroused by computers but declares that on balance they will create many more new jobs, conveniences, and business efficiencies.

"THINK"

IBM's new brain is a logical extension of the company's famed slogan, "THINK." In the age of giant electronic brains, IBM's President Thomas J. Watson Jr. is applying to machines the slogan which his father, IBM's Board Chairman Thomas J. Watson Sr., applied only to men. President Watson hopes to mechanize hundreds of processes which require the drab, repetitive "thought" of everyday business. Thus liberated from grinding routine, man can put his own brain to work on problems requiring a function beyond the capabilities of the machine: creative thought. Says Watson: "Our job is to make automatic a lot of things now done by slow and laborious human drudgery. A hundred years ago there was an industrial revolution in which seven to ten horsepower was put behind each pair of industrial hands in America. Today we're beginning to put horsepower behind office hands, electric energy in the place of brain power."

IBM is not the only company with the idea of automating U.S. offices. In the fast-growing business equipment industry, such big firms as National Cash Register, Burroughs Corp. and Remington Rand are busy making everything from adding machines to the new electronic computers. But IBM is the biggest of all with 25% of the two billion dollar industry. . . .

The Automatic Factory

Businessmen already envision a day when the brains will be used not only for paperwork problems, but to operate factories, to run auto production lines or any plant where a process can be reduced to a preset, repetitive system. Swiftly and obediently, the big robot will start and stop production lines, supervise all the machines, correct faulty workmanship, inspect the finished product, package it and ship it out to U.S. consumers.

The mere vision of such total automation for industry has touched off a siren of alarm among U.S. labor unions; they fear that the already swift spread toward automation will throw thousands of workers out of jobs. Before a congressional committee investigating the stock market last week . . . , General Motors President Harlow H. Curtice took special care to debunk the bugaboo. Said he: "Automation is the making of tools to produce more efficiently . . . its progress."

For every job lost, a dozen more interesting, better-paying jobs will open up in the making and servicing of machines.

In such progress, some workers may indeed be displaced by machines. But for every job lost, a dozen more interesting, better-paying jobs will open up in the making and servicing of machines. Says Tom Watson Sr.: "Automation will develop as all other forms of power. Primitive man had only his hands, then animal power, then wind power—windmills and sailing ships—then came steam and electric power, and gasoline and oil power, and now, atomic power. Not one of these powers ever canceled out the powers we already had. In every development we made, the original power—manpower—became more valuable than ever. Never in history has man gotten higher rates of pay for his work than he is getting today."

The Perennial Fallacy

Nowhere is the fallacy of unemployment from automation more evident than in offices. There, automation has made its greatest strides, helped along by dozens of whirring, clicking machines. Yet the number of office workers has actually risen from 5,100,000 to 8,100,000 in the last ten years. Only the new machines have made it possible for U.S. businessmen to keep up with the increasing flood of paper work. There are automatic time clocks, electric typewriters, card punchers, sorters, analyzers, tabulating machines and accounting machines. They do everything from keeping records to servicing bank accounts and writing checks. The U.S. Government alone uses 23,150 tabulating machines (more than 90% made by IBM).

To fill new needs, IBM has just brought out a "Cardatype" machine, which can do a complete accounting job, has electric typewriters type out the finished accounts from punched cards, all automatically. They can do and type as many as five separate accounts simultaneously. IBM also has a new super-time-clock system, in which one master clock regulates all lights, air conditioning, heating, doors and vaults in a plant. For example, a few minutes before 9 o'clock each morning, the machine can open the doors, flick on lights, turn on heat or the air conditioner; at closing time it shuts up shop without human help. . . .

Beyond office paper work, the entire horizon of factory automation is beginning to open up for electronics. While U.S. industry has always had automatic machines, a whole new family of "feedback" controls is growing up which not only run the machines, but also correct their mistakes, order the machines to rework defective parts until they are perfect. Such feedback controls are the forerunner of real automation. Linked together, they will make automated production lines. A form of the new automation is already at work making telephone relays for Western Electric, acetylene gas and carbide for the National Carbide division of Air Reduction Co., aircraft engines at Curtiss-Wright. Other firms, such as American Smelting & Refining, General Mills, Dunlop Tire & Rubber, have turned to automatic controls to produce everything from bronze castings to printed circuits and foam-rubber mattresses. In the oil industry, automation has advanced to the point where a handful of technicians can run an entire $40 million plant by remote control from a panel of instruments. In some of the newer refineries now under construction, there will even be controls to watch the instruments, run the cracking processes from start to finish without human help. . . .

The Golden Age

Total automation is a long step away. But the prospects for mankind are truly dazzling. Automation of industry will mean new reaches of leisure, new wealth, new dignity for the laboring man. The coalpit worker, the steel puddler, and those who do many maintenance jobs on an assembly line can surrender to self-controlled electronic machines the hazards and dullness of backbreaking menial work. Thus liberated, the world's laboring man can find a new pleasure and culture in life.

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Actually, automation is not a threat against jobs, but a real necessity for an expanding economy. Despite the progress towards office automation, businessmen must move even faster to keep up with the mountain of paperwork growing out of the increasing complexity of production and industry. To date, only 5% of office work is done by automatic machines. There is no reason in IBM's mind why businessmen could not mechanize more than 35% of their office work. This would not only speed it up but save billions of dollars.

In the same way, industry must speed up automation in factories. By 1965, if the standard of living is to keep on rising, the U.S. will require at least a 50% increase in gross national product. By then, the U.S. population will hit 190 million, but since much of it will consist of school-age children and oldsters, there will actually be relatively fewer effective workers in the labor force. To keep up with production requirements, U.S. industry must rely on more automation. Can the breach be filled? IBM and its team of Watsons have no doubt it will be. Says Tom Watson Sr.: "In the next 40 years we will accomplish so much more than in the past 40 that people will wonder why we didn't do more in the first 40."

11 Watson and Petre, **Father, Son & Co.**, 337-38.

In the early 1960s, Watson, a Democrat, was appointed to a committee on labor management policy in the Kennedy administration that included other business leaders such as Henry Ford II and labor leaders such as George Meany and Walter Reuther. Here Watson recalls learning about the human costs when corporate changes threw people out of work and in response endorsed policies to help the victims.

My specialty on this panel was the relationship between unemployment and automation. At IBM we'd always taken a fairly hard line on that issue—after all, we sold punch-card machines on the basis of how many clerks they'd replace. Dad justified this by pointing out that modern technology improves industrial productivity, which in turn boosts the economy, creates jobs, and raises the standard of living for everyone. But now I became conscious of the workers who get put on the street in the process. What first woke me up was a 1960 television documentary by Edward R. Murrow. I appeared in it to explain the IBM point of view, but it was the show's opening scene that became indelibly imprinted on my mind. Murrow started with the meat packers. In his clear and forceful way, he laid out the background, and then he interviewed an unemployed man who was just sitting on his stoop. The fellow had worked in a slaughterhouse but his skill had been replaced by a machine. He was only forty-five or fifty, but there was nothing he could reapply himself to, and the disintegration of his morale came through on the screen. I was stunned by the tragedy of an able man sitting there saying he wanted to work but couldn't get a job because the whole industry had changed.

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Walter Reuther had a tremendous influence on me. Lots of people called Reuther a Communist because he and his brother had worked in a Soviet automobile factory in the early 1930s. He was anything but a Communist; I believe he was one of America's great men and that his death in a plane crash in 1970 was a tragedy for the country. When it came to my education, Reuther picked up where Murrow had left off. He made me understand that if Buick decides to close an obsolete plant in Detroit, then builds a modern new plant in the South, five thousand people are still thrown out of work; the new jobs in Tennessee don't mean very much to those workers in Detroit. Conservatives would probably argue that that's part of the free-enterprise system, and that those families are just the chaff that gets ground out while the mill is working beautifully. But I don't think that's right, and the labor management committee studied the methods Europeans use to protect jobs. We talked at length with the Swedes, in particular. They have cooperative programs involving industry, labor, and government to recruit workers from sections of the country where unemployment is high, retrain them, and move them to areas where they are needed. Kennedy was willing to explore any idea for inspiring a similar kind of cooperation in the United States.

Betting the Company: the Creation of IBM System 360

IBM might have rested on its commercial laurels, lining up with the don't-rock-the-boat norms of the 1950s. Its personnel were expected to dress in a standard style – coats and ties for the men, not only in the sales force but in the laboratories — and behave like church deacons. Cultural observers found the 1950s a period of conformity, where Americans took their cues from what other people expected of them. But for IBM at least, outward appearances were deceptive. Tom Watson Jr. was an enemy of the pressure for political conformity represented by Senator Joseph McCarthy, and had the same attitude to innovation within a giant corporation, He was iconoclastic, a restless innovator who fostered competition between groups in his own company that would keep it ahead of the competition. To win, he remembered, IBM had to "move, move, move all the time." The company's scientists and engineers may have looked stuffy in their coats and ties, but when it came to mainframe computers they were revolutionaries. In the early 1960s, Watson took an unprecedented gamble. He risked the *company in giving them approval to designan all-round computer system thatcould run any specialized software and thus perform tasks for any sector on the compass of information processing. This was System 360. It would set the standard for mainframes and sustain IBM's* dominance in mainframe computers for a generation.

12 T. A. Wise, "IBM's $5,000,000,000 Gamble," **Fortune**, Sept. 1966, pp. 118 ff.

This article, published in one of the nation's leading magazines of business, lays out the magnitude and boldness of the risk that IBM took in betting the company on the System 360.

The decision by the management of the International Business Machines Corp. to produce a new family of computers, which it calls the System/360, has emerged as the most crucial and portentous -- as well as perhaps the riskiest - business judgment of recent times. The decision committed IBM to laying out money in sums that read like the federal budget -- some $5 billion over a period of four years. To launch the 360, IBM has been forced into sweeping organizational changes, with executives rising and falling with the changing tides of the battle. Although the fact has largely escaped notice, the very character of this large and influential company has been significantly altered by the ordeal of the 360, and the way it thinks about itself has changed, too. Bob Evans, the line manager who had the major responsibility for designing this gamble of a corporate lifetime, was only half joking when he said: "We called this project 'You bet your company.' " . . .

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The new System/360 was intended to obsolete virtually all other existing computers — including those being offered by IBM itself. Thus the first and most extraordinary point to note about this decision is that it involved a challenge to the marketing structure of the computer industry — an industry that the challenger itself had dominated overwhelmingly for nearly a decade. It was roughly as though General Motors had decided to scrap its existing makes and models and offer in their place one new line of cars, covering the entire spectrum of demand, with a radically redesigned engine and an exotic fuel.

The computer is recognized as the most vital tool of management introduced in this generation. It increasingly affects not only business corporations, but government and education as well. There are now perhaps 35,000 computers in use, and it has been estimated that there will be 85,000 by 1975. IBM sits astride this exploding market, accounting for something like two-thirds of the worldwide business — i.e., the dollar value of general-purpose computers currently installed or on order. IBM's share of this market last year represented about 77 percent of the company's $3.6-billion gross revenues, and probably accounted for about the same share of IBM's profits, which totaled $477 million.

The cost of carrying out 100,000 computations on the first-generation model was $1.38; the 360 will reduce the cost to 3½ cents.

Several separate but interrelated steps were involved in the launching of System/360. Each one of the steps involved major difficulties, and taking them all meant that IBM was accepting a staggering challenge to its management capabilities. First, the 360 depended heavily on micro-circuitry, an advanced technology in the field of computers. . . . In a 1952 vacuum-tube model of IBM's first generation of computers, there were about 2,000 components per cubic foot. In a second-generation machine, which used transistors instead of tubes, the figure was 5,000 per cubic foot. The System/360 model 75 computer, using hybrid micro-circuitry, involves 30,000 components per cubic foot. The old vacuum-tube computer could perform approximately 2,500 multiplications per second; the 360 model 75 was designed to perform 375,000 per second. The cost of carrying out 100,000 computations on the first-generation model was $1.38; the 360 will reduce the cost to 3½ cents.

The second step was the provision for compatibility — that is, as the users' computer requirements grew, they could move up from one machine to another without having to discard or rewrite already existing programs. Limited compatibility had already been achieved by IBM, and by some of its competitors too, for that matter, on machines of similar design but different power. But it had never been achieved on a broad line of computers with a wide range of powers, and achieving this compatibility depended as much on developing compatible programs or "software" as it did on the hardware. All the auxiliary machines — "peripheral equipment" as they are called in the trade — had to be designed so that they could feed information into or receive information from the central processing unit; this meant that the equipment had to have timing, voltage, and signal levels matching those of the central unit. In computerese, the peripheral equipment was to have "standard interface." The head of one competing computer manufacturing company acknowledges that at the time of the System/360 announcement he regarded the IBM decision as sheer folly and doubted that IBM would be able to produce or deliver a line that was completely compatible.

Finally — and this was the boldest and most perilous part of the plan — it was decided that six main units of the 360 line, originally designated models 30, 40, 50, 60, 62, and 70, should be announced and made available simultaneously. (Models at the lower and higher ends of the line were to be announced later.) This meant that all parts of the company would have to adhere to a meticulous schedule.

Up in manufacturing, down in cash

The effort involved in the program has been enormous. IBM spent over half a billion dollars on research and development programs associated with the 360. This involved a tremendous hunt for talent: by the end of this year, one-third of IBM's 190,000 employees will have been hired since the new program was announced. Between that time, April 7, 1964, and the end of 1967, the company will have opened five new plants here and abroad and budgeted a total of $4.5 billion for rental machines, plant, and equipment. Not even the Manhattan Project, which produced the atomic bomb in World War II, cost so much (the government's costs up to Hiroshima are reckoned at $2 billion), nor, probably, has any other privately financed commercial project in history. . . .

The missionaries and the scientists

Oddly enough, the upheaval at IBM during the past two years went largely unnoticed. The company was able to make itself over more or less in private. It was able to do so partly because IBM is so widely assumed to be an organization in which the unexpected simply doesn't happen. Outsiders viewing IBM presume it to be a model of rationality and order—a presumption related to the company's products, which are, of course, instruments that enable (and require) their users to think clearly about management.

This image of IBM, moreover, has been furthered over the years by the styles of the two Watsons. Tom Watson Sr. combined an intense devotion to disciplined thinking with formal, rather Victorian attitudes about conduct, clothes, and courtesy. The senior Watson's hostility toward drinking, and his demand that employees dedicate themselves totally to the welfare of the corporation, created a kind of evangelical atmosphere. When Tom Watson Jr. took over from his father in 1956, the manner and style shifted somewhat, but the missionary zeal remained — now overlaid by a new dedication to the disciplines of science. The overlay reinforced the image of IBM as a chillingly efficient organization, one in which plans were developed logically and executed with crisp efficiency. It was hard to envision the company in a gambling role.

The dimensions of the 360 gamble are difficult to state precisely. The company's executives, who are men used to thinking of risks and payoffs in hard quantitative terms, insist that no meaningful figure could ever be put on the gamble – i.e., on the odds that the program would be brought off on schedule, and on the costs that would be involved if it failed.

13 William H. Whyte Jr., **The Organization Man** (Garden City, NY: Doubleday & Company, 1956), 231-38.

IBM's System/360 venture appeared to run contrary to the standards of corporate behavior in the 1950s. In The Organization Man, one of the most popular books of the 1950s, William H. Whyte Jr., a well-known business journalist, spelled out the culture of conformity and resistance to risk-taking that seemed to mark many high-technology companies at the time, castigating them for discouraging free-wheeling, impractical research that was driven by curiosity and for intolerance of the free-spirited scientists or engineers whose work was driven by curiosity.

To some management people the desire to do "free" work is a downright defect—a symptom of maladjustment that demands cure, not coddling. When a man wants to follow his own hunch, they believe, this is a warning that he is not "company-oriented." The solution? Indoctrination. In "Personnel Practices in Industrial Laboratories" (Personnel, May 1953) Lowell Steele puts the issue squarely. "Unless the firm wants to subsidize idle curiosity on the part of its scientists," he says, "it must aid them in becoming `company-conscious.' " Company loyalty, in other words, is not only more important than idle curiosity; it helps prevent idle curiosity.

The administrators are perfectly correct. If they get scientists to be good company men like other normal people, they won't be bothered much by scientists' following their curiosity. The policy will keep out that kind of scientist. For what is the dominant characteristic of the outstanding scientist? Every study has shown that it is a fierce independence.

In her study of eminent scientists, psychologist Anne Roe found that what decided them on their career almost invariably was a college project in which they were given free rein to find things out for themselves, without direction, and once the joys of freedom were tasted, they never lost the appetite. The most important single factor in the making of a scientist, she concludes, is "the need and ability to develop personal independence to a high degree. The independence factor is emphasized by many other findings: the subjects' preference for teachers who let them alone, their attitudes toward religion . . . their satisfaction in a career in which, for the most part, they follow their own interests without direction or interference." (Scientific American, Nov. 1952.)

In the outstanding scientist, in short, we have almost the direct antithesis of the company-oriented man. If the company wants a first-rate man it must recognize that his allegiance must always be to his work. For him, organization can be only a vehicle. What he asks of it is not big money —significantly, Bell Labs and GE have not had to pay higher salaries than other research organizations to attract talent. Nor is it companionship, or belongingness. What he asks is the freedom to do what he wants to do.

In the outstanding scientist… we have almost the direct antithesis of the company-oriented man.

For its part, The Organization can ask only so much in return. The Organization and he have come together because its long-range interests happen to run parallel with what he wants to do. It is in this, his work, that The Organization's equity in him lies. Only one quid pro quo can it properly ask for the money that it gives him. It can ask that he work magnificently. It cannot ask that he love The Organization as well.

And what difference would it make if he did? The management man is confusing his own role with that of the scientist. To the management man such things as The Organization and human relations are at the heart of his job, and in unconscious analogy he assumes that the same thing applies to the scientist, if perhaps in lesser degree. These things are irrelevant to the scientist—he works in an organization rather than for it. But this the administrator cannot conceive; he cannot understand that a man can dislike the company—perhaps even leave in disgust after several years—and still have made a net contribution to the company cash register infinitely greater than all of his better-adjusted colleagues put together.

Thus, searching for their own image, management men look for the "well-rounded" scientists. They don't expect them to be quite as "well rounded" as junior-executive trainees; they generally note that scientists are "different." They do it, however, in a patronizing way that implies that the difference is nothing that a good indoctrination program won't fix up, Customarily, whenever the word brilliant is used, it either precedes the word but (cf. "We are all for brilliance, but . . .") or is coupled with such words as erratic, eccentric, introvert, screwball, etc. To quote Mr. Steele again, "While industry does not ignore the brilliant but erratic genius, in general it prefers its men to have 'normal' personalities. As one research executive explained, `These fellows will be having contact with other people in the organization and it helps if they make a good impression, They participate in the task of "selling" research.' " . . .

Management has tried to adjust the scientist to The Organization rather than The Organization to the scientist.

Management has tried to adjust the scientist to The Organization rather than The Organization to the scientist. It can do this with the mediocre and still have a harmonious group. It cannot do it with the brilliant; only freedom will make them harmonious. Most corporations sense this, but, unfortunately, the moral they draw from it is something else again. A well-known corporation recently passed up the opportunity to hire one of the most brilliant chemists in the country. They wanted his brilliance, but they were afraid that he might "disrupt our organization." Commenting on this, a fellow scientist said, "He certainly would disrupt the organization. He is a man who would want to follow his own inclinations. In a laboratory which understood fundamental research, he wouldn't disrupt the organization because they would want him to follow his own inclinations. But not in this one."

Even when companies recognize that they are making a choice between brilliance and mediocrity, it is remarkable how excruciating they find the choice. . . . Listening to some of industry's pronouncements, one would gather that it is doing everything possible to ward off the kind of brilliant people who would force such a choice. Here, in this excerpt from a Socony-Vacuum Oil Company booklet on broad company policy, is a typical warning:

No Room for Virtuosos

> Except in certain research assignments, few specialists in a large company ever work alone. There is little room for virtuoso performances. Business is so complex, even in its non-technical aspects, that no one man can master all of it; to do his job, therefore, he must be able to work with other people.

The thought is put even more forcibly in a documentary film made for the Monsanto Chemical Company. The film, which was made to inspire young men to go into chemistry, starts off in the old vein. You see young boys dreaming of adventure in faraway places as they stand by the station in a small town and watch the trains roll by. Eventually the film takes us to Monsanto's laboratories. We see three young men in white coats talking to one another. The voice on the sound track rings out: "No geniuses here; just a bunch of average Americans working together."

This was no mere slip of the script writer's pencil. I had a chance later to ask a Monsanto executive why the company felt impelled to claim to the world that its brainwork was carried on by just average Americans. The executive explained that Monsanto had thought about the point and wanted to deter young men from the idea that industrial chemistry was for genius types. At the very moment when genius types couldn't agree more, the timing hardly seems felicitous. It could be argued, of course, that since the most brilliant stay in the universities anyway, management's barriers against genius would be at worst unnecessary. But it is not this clear-cut; whether or not they have geniuses, companies like Monsanto do not have their research work carried on by just average Americans, and if they did the stockholders would do well to complain. As Bell Labs and General Electric prove, there are many brilliant men who will, given the right circumstances, find industrial research highly absorbing. For company self-interest, let alone society's, a management policy that repels the few is a highly questionable one.

Society would not be the loser if the only effect on management policy were to make the most brilliant stay in the university. This screening effect, however, is only one consequence of management's policy. What concerns all of us, just as much as industry, is the fact that management also has a very powerful molding effect on the people it does get. They may not all be geniuses, but many are highly capable men, and in the right climate they could make great contributions.

That management is not only repelling talent but smothering it as well is told by management's own complaints. Privately, many of the same companies which stress team play criticize their young Ph.D.s for not being interested enough in creative work—or, to put it in another way, are a bunch of just good average Americans working together. "Practically all who are now Ph.D.s want to be told what to do," one research leader has complained. "They seem to be scared to death to think up problems of their own." Another research leader said that when his firm decided to let its chemists spend up to 25 per cent of their time on "free" work, to the company's surprise hardly any of the men took up the offer.

But it shouldn't be surprising. A company cannot bring in young men and spend several years trying to make them into one kind of person, and then expect them, on signal, to be another kind. Cram courses in "brainstorming" and applied creativity won't change them. If the company indoctrinates them in the bureaucratic skills and asks them to keep their minds on the practical, it cannot suddenly stage a sort of creative play period and then, on signal, expect them to be like somebody else. . . .

Kodachrome… was perfected in Eastman's huge laboratories but was invented by two musicians in a bathroom.

Those who see the growing concentration of technology in Big Business as irrevocable argue that advances are no longer possible except with the huge laboratories and equipment which only the big corporations can afford. But this is not true.

For some scientific ends elaborate facilities—cyclotrons for physicists, ships for oceanographers—are necessary means. But this is only part of the picture; historically, almost every great advance has been made by one man with a minimum of equipment—sometimes just paper and pencil—and though this is more true of fundamental research, it is true of applied research as well. Go down the list of commercial inventions over the last thirty years: with very few exceptions the advances did not come from a corporation laboratory. Kodachrome, for example, was perfected in Eastman's huge laboratories but was invented by two musicians in a bathroom. The jet engine is an even clearer case in point. As Launcelot Law Whyte points out, none of the five earliest turbo-jet developments of Germany, Britain, and the United States was initiated within an established aircraft firm. "It is usually the relatively isolated outsider," Whyte says, "who produces the greatest novelties. It is a platitude, but it is often neglected."

Because it is small, the small firm has one potential advantage over the big one. It can't afford big research teams to administrate or interlocking committees to work up programs, and it doesn't have a crystallized company "family" to adjust to. Because it hasn't caught up yet with modem management, to put it another way, it provides an absence of the controls that make the scientist restive. Few small corporations have seized the opportunity, and at this writing there is no sign they ever will. But the opportunity is there.

14 Tedlow, **The Watson Dynasty**, 210-13.

Tedlow recounts how Watson promoted risk-taking innovation within IBM through the method of "contention management," a managerial strategy that pitted one research and development group against another in competition for optimal solutions to broad goals.

With business moving ahead so quickly, one might assume that an atmosphere of happiness, perhaps even playfulness, pervaded IBM from top to bottom. One would be quite wrong. Watson's family life had been full of competition and argument. That spilled over into his professional life when, during the decade after World War II, he and Dad had their "hellacious" fights. Watson had no intention of seeing that gut-clutching way of life disappear merely because his father had passed away.

Around the time of the Williamsburg conference, Watson formalized in his own thinking what had been de facto conduct at IBM since the early 1950s, as his control of operations increased. This was what became well known not only in the industry but in business generally as the system of "contention management." It was a mode of running a company that Watson saw as completely different from his father's. His father attracted sycophants, who disgusted young Tom. The combination of Dad's uncontrollable temper and his unquenchable need for praise had, in his son's view, "silenced too many people."

Under contention management, there would be no silence. To the contrary, there would be as much fighting as in the good old days when Dad and Watson had their "primal" battles. Contention management institutionalized fighting. "Not only did it make staff versus line conflicts acceptable; it actually encouraged them." These conflicts either resulted in eventual consensus or were moved to a higher level. The contending line and staff men would have to "air their differences before the corporate management committee, which did not suffer indecisiveness gladly . . . The best way to motivate people," Watson declared with more self-assurance than the topic permits a prudent man to possess, "is to pit them against one another, and I was constantly looking for ways to stimulate internal competition." What Watson had with Dad from 1945 to 1956 he wanted to metastasize throughout the whole company.

There are a couple of observations which call out to be made about all this. First, although internal competition did work in Watson's IBM and has worked elsewhere, internal cooperation can also work. There is such a thing as team play not only in sports but in business and indeed in life. True teamwork can mobilize the power of the spirit of self-sacrifice. When one person says to another—"Life is not a seesaw where I'm down if you're up; it is the opposite: Your success is my success"—the enormous power of generosity is unleashed. Great things have been done with this approach to challenges. To state as an immutable principle of human nature that the "best way to motivate people is to pit them against one another" is highly questionable. It is true if that is the business culture you foster. But it is very far indeed from some eternal verity.

IBM came to be known by insiders as "I've Been Moved"

Another aspect of human relations at IBM under Watson is noteworthy. The company moved people around a lot—both geographically (IBM came to be known by insiders as "I've Been Moved") and with regard to their assignments. If a man was promoted to a job that was over his head, he would be reassigned "to a level where he could perform well." In this process, according to Watson, "we would sometimes strip a man of a fair amount of his dignity, but we would then make a great effort to rebuild his self-respect."

This "recycling" of executives can be done successfully and is a practice some well-run companies use today. Intel is an example. But it is a process which must be managed with exquisite tact, a trait for which IBM was not famous. . . .

Many things could be said of the executive corps Watson put together, but apparently "nice" was not a word one would use to describe them as a group. The enemy of effective business management, in Watson's view, was "the nice guy you like to go on fishing trips with":

> Instead I was always looking for sharp, scratchy, harsh, almost unpleasant guys who could see and tell me about things as they really were. If you can get enough of those around you, and have patience enough to hear them out, there is no limit to where you can go.

When he looked in the mirror, Watson saw a "pretty harsh and scratchy guy myself."

Watson declared that his “most important contribution” to IBM was “my ability to pick strong and intelligent men . . . and then hold them together by persuasion, by apologies, by speeches, by discipline, by thoughtfulness . . . , and by using every tool at my command to make each man think I was a decent guy." When he looked in the mirror, Watson saw a "pretty harsh and scratchy guy myself."

Watson wanted every executive at IBM to feel the urgency he felt—"whatever they did, it was never enough." He knew that he was hiring men who were intellectually his superior; but he felt he could make a vital contribution by driving them as hard as he could.

Is this the best way to run a company? Had Watson been asked, he could have said what Dad said when people complained about his leadership: "Look at the record."

The business world is full of tension, and there are many companies populated by shouters and screamers. "Acting out," as a psychiatrist would call this sort of thing, can serve to relieve stress. On the other hand, there are plenty of companies which have done very well without manufacturing melodrama. . . .

15 Watson and Petre, **Father, Son & Co.**, 346-51.

Here is Watson's own account of his reasons for embarking on the innovation of the 360 and the managerial strategy he used to reach the goal. Just as IBM's move into electronic computing encountered resistance from groups within the company who were heavily invested in punch-card machines, so the initiative of the 360 was resisted by IBM people who were deeply involved with the company's existing family of computers: they preferred incremental improvements rather than a radical departure in computer design. Watson overcame them with his own decisiveness and with the help of comparably strong-minded executives. Chief among them was Vin Learson, a tough, clever manager and forceful personality who was as competitive as Watson himself.

We'd been getting ready to announce a new family of computers that was radically different from anything that had ever been built. This new line was named System/360—after the 360 degrees in a circle—because we intended it to encompass every need of every user in the business and the scientific worlds. Fortune magazine christened this project "IBM's $5,000,000,000 Gamble" and billed it as "the most crucial and portentous—as well as perhaps the riskiest—business judgment of recent times." Building this new line meant putting IBM through tremendous upheavals. Careers were made and broken, and the mistakes we made along the way changed a lot of lives, including . . . my own. The expense of the project was indeed staggering. We spent three quarters of a billion dollars just on engineering. Then we invested another four and a half billion on factories, equipment, and the rental machines themselves. We hired more than sixty thousand new employees and opened five major new plants. It was the biggest privately financed commercial project ever undertaken. The writer at Fortune pointed out that it was substantially larger than the World War II effort that produced the atom bomb.

The need for System/360 emerged from an odd set of circumstances. In the early 1960s computing was finally coming into its own. Some of the wonders that people had confidently predicted right after the war—such as automated weather forecasting—had failed to materialize, but the machines had been put to use every place else, from the monthly mailing of electric bills to the space race. Computers were beginning to revolutionize everyday life. For example, American Airlines was about to unveil its SABRE reservation system, linking ticket agents all over the United States to a master computer in Westchester County, and making it possible for customers to book airline seats without having to put up with the traditional overnight wait for confirmation. We could imagine much broader horizons ahead. One idea that appealed to me was placing computer terminals in America's classrooms to help raise the standard of education. Meanwhile visionaries began talking about the day when computer power would be delivered to homes just like telephone service and electricity.

Paradoxically, there also was a feeling in the early '60s that IBM had reached a plateau. We were still expanding, but less quickly than before—in the year Kennedy beat Nixon, for example, we only grew nine percent. As we reached the two billion-dollars-a-year mark people began to speculate that we'd gotten so big that naturally our growth rate had to fall. But given the bright prospects for computing, that seemed illogical, and I thought it was probably our own fault that we were slowing down. The two separate computer divisions I'd created were competing with each other fiercely, just as I'd hoped, but one unhappy side effect was that our product line became wildly disorganized. By September 1960, we had eight computers in our sales catalog, plus a number of older, vacuum-tube machines. The internal architecture of each of these computers was quite different, so different software and different peripheral equipment, such as printers and disk drives, had to be used with each machine. If a customer's business grew and he wanted to shift from a small computer to a large one, he had to get all new everything and rewrite all his programs, often at great expense.

… applying a management technique called "abrasive interaction."

The man whose job it was to spur IBM's growth rate was Vin Learson, who at this point was vice president and group executive in charge of our manufacturing and development divisions. He thought the obvious answer was to simplify the product line, and he asked the technical people to try. But at first this request had very little effect because the engineers of each division were wedded to their own machines. The amazing thing about Vin, apart from the tremendous force of his personality, was his cleverness as a manager. He saw that it was time to break down the rivalry between the two divisions, and he did it by applying a management technique called "abrasive interaction." This meant forcing people to swap sides: taking the top engineer from the small-computer division and making him boss of the best development team in the large-computer division. A lot of people thought this made about as much sense as electing Khrushchev president, but after interacting abrasively for some months those engineers earned one another's respect, just as Vin anticipated. Slowly they worked their way around to the idea of building a single computer line that would span the entire market. Vin made this group of engineers the core of a much larger committee called SPREAD—an acronym for Systems Programming, Research, Engineering, And Development—whose charter was to map out a new product strategy. The SPREAD committee met for a couple of months late in 1961, and when it was slow producing a report, Vin got impatient. Two weeks before Christmas he sent them to a motel in Connecticut with orders not to come back until they'd agreed. That was how the plan for System/360 was born—in the form of an eighty-page report delivered on December 28.

During the year of the SPREAD report I was busy on presidential committees in Washington and followed the technical debates within the computer divisions only from a distance. But by the middle of 1962 enough had gone wrong that I was spending a lot more time at the office. The stock market that May had its biggest drop since 1929, and IBM stock got hammered along with the rest, losing about one third of its value—its first major decline in thirty years. That alone would have been enough to reel me in, and with the 360 on the way, I began to get a hollow feeling in the pit of my stomach about the risks we faced. IBM had always succeeded by making bold moves, but the System/360 plan was dramatic even by our standards.

Once a customer entered the circle of 360 users, we knew we could keep him there for a very long time.

Vin was the father of the new line of machines. His intention was to make all other computers obsolete—including the thousands of machines on which we were then collecting rent—and to replace them with a completely new family of processors, ranging from little machines renting for $2,500 per month to high-performance giants renting for more than $115,000 per month. The machines would all embody a revolutionary new feature called compatibility, which meant that, despite their great variation in size, they'd be able to use the same software and hook up to the same disk drives, printers, and other peripherals. Once customers shifted to System/360, they'd be able to expand their installations simply by mixing and matching components from our sales catalog. That was good for them, and the benefit for IBM was equally compelling—once a customer entered the circle of 360 users, we knew we could keep him there for a very long time.

From the beginning we faced two risks, either of which alone was enough to keep us awake nights. First there was the task of coordinating the hardware and software design work for the new line. We had engineering teams all over America and Europe working simultaneously on six new processors and dozens of new peripherals—disk drives, tape drives, printers, magnetic and optical character readers, communications equipment, and terminals—but in the end all this hardware would have to plug together. The software was a bigger hurdle still. In order for System/360 to have a consistent personality, hundreds of programmers had to write millions of lines of computer code. Nobody had ever tackled that complex a programming job, and the engineers were under great pressure to get it done.

Our other source of worry was that we were trying for the first time to manufacture our own electronic parts. The electronics industry, after having progressed very fast during the 1950s from the vacuum tube to the transistor, was on the verge of another transformation. The wave of the future was integrated circuits—computer chips that incorporate transistors, resistors, diodes, and so on, all in a single tiny unit. Nobody was using integrated circuits in computers yet, but the System/ 360 design called for a lot of them. Al Williams argued that even though we'd relied on suppliers to provide the earlier generations of components, we had to manufacture these ourselves. "Whole computers are going to shrink down onto these devices," he said. "When that happens, do you think we'll want to be buying them from outsiders? If we're going to stay in the computer business, we'd better learn how to make these things ourselves." I agreed, but I'll never forget how expensive it was to build our first integrated circuit factory. Ordinary plants in those days cost about forty dollars per square foot. In the integrated circuit plant, which had to be kept dust-free and looked more like a surgical ward than a factory floor, the cost was over one hundred fifty dollars. I could hardly believe the bills that were coming through, and I wasn't the only one who was shocked. The board gave me a terrible time about the costs. "Are you really sure you need all this?" they'd say. "Have you gotten competitive bids? We don't want these factories to be luxurious."

Sales offices were sending in panicky reports that they could no longer hold the line against the competition.

Our original intent was to announce the first machines in April 1964 and gradually phase out the old product line by unveiling the rest over eighteen months. Unfortunately we'd miscalculated how much time we had, and the flaws in our existing product line caught up with us a year or two sooner than we'd anticipated. By spring 1963 the old computers were obsolete. We did a technical study showing that while the 360s were going to be better than the latest computers from RCA, Burroughs, Honey-well, Univac, and General Electric, all those competitive machines were superior to our existing line. A number of them offered two to three times the performance of our computers for the same price. Our salesmen were hamstrung—since System/360 had not yet been announced, and none of them even knew what we were planning, they had nothing to tell customers. By the middle of 1963, sales offices were sending in panicky reports that they could no longer hold the line against the competition. Even though demand for computers increased by well over 15 percent that year, IBM grew only seven percent, our lowest growth since the war.

The only solution was to get System/360 out the door fast, and a number of executives argued that we ought to launch the whole thing at once. This would surely make a tremendous splash in the market. Customers would see how they'd be able to grow with the product line, so we could persuade them to wait for the 360s to be produced instead of jumping to competitors. But there were big disadvantages. For one thing, although the new computers were nearly ready, not all of them had gone through the rigorous testing we required. A bigger danger was that once we started accepting orders, our factory network would be under tremendous strain to deliver every item in an enormously complicated new product line. There wasn't going to be much room for error.

It was the biggest, riskiest decision I ever made, and I agonized about it for weeks, but deep down I believed there was nothing IBM couldn't do. And so on April 7, 1964—almost exactly fifty years after my father first came to work at IBM—we staged a product announcement that would have made him proud. To attract maximum publicity, we held press conferences in sixty-three U.S. cities and fourteen foreign countries, while tens of thousands of guests all over the world showed up for customer briefings. A chartered train carried two hundred reporters in New York from Grand Central Terminal to Poughkeepsie, where the main announcement was made. I presented the 360 as "the most important product announcement in company history," and the visitors were shown into a large display hall where six new computers and forty-four new peripherals stretched before their eyes.

Within IBM there was a great feeling of celebration because a new era was opening up. But when I looked at those new products, I didn't feel as confident as I'd have liked. Not all of the equipment on display was real; some units were just mockups made of wood. We explained this to our guests, so there was no deception. But it was a dangerous cutting of corners—not the way I think business ought to be done—and an uncomfortable reminder to me of how far we had to go before we could call the program a success.