10

THE SHAPING OF THE PERSONAL COMPUTER

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NO HISTORIAN HAS yet written a full account of the personal computer. Personal computing was perhaps the most life-changing consumer phenomenon of the second half of the twentieth century, and it continues to surprise in its ever-evolving applications and forms. If we consider an earlier invention, domestic radio, it took about fifty years for historians to start writing really satisfactory accounts. We should not expect to fully understand the personal computer in a lesser time scale.

There has, of course, been no shortage of published accounts of the development of the personal computer by journalists. Much of this reportage is bad history, though some of it makes for good reading. Perhaps its most serious distortion is its focus on a handful of individuals, portrayed as visionaries who saw the future and made it happen: Apple Computer's Steve Jobs and Microsoft's Bill Gates figure prominently in this genre. By contrast, IBM and the established computer firms are usually portrayed as dinosaurs: slow-moving, dim-witted, deservedly extinct. When historians write this history, it will be more complex than these journalistic accounts. The real history lies in the rich interplay of cultural forces and commercial interests.

RADIO DAYS

If the idea that the personal computer was shaped by an interplay of cultural forces and commercial interests appears nebulous, it is helpful to compare the development of the personal computer with the development of radio in the opening decades of the twentieth century, whose history is well understood. There are some useful parallels in the social construction of these two technologies, and an understanding of one can deepen one's understanding of the other.

In the 1890s the phenomenon we now call radio was a scientific novelty in search of an application. Radio broadcasting as we now know it would not emerge for a generation. The first commercial application of the new technology was in telegraphy, by which Morse signals were transmitted from one point to another—a telegraph without wires. Wireless telegraphy was demonstrated in a very public and compelling way in December 1901 when Guglielmo Marconi transmitted the letter S repeatedly in Morse across the Atlantic from Poldu in Cornwall, England, to St. Johns, Newfoundland, Canada. Banner newspaper headlines reported Marconi's achievement, and his firm began to attract the attention of telegraph companies and private investors.

Over the next few years, wireless telegraphy was steadily perfected and incorporated into the world's telegraph systems, and voice transmission and marine-based telegraphs were developed. The latter, particularly, captured many headlines. In 1910 a telegraph message from the *S.S. Montrose* resulted in the capture of the "acid-bath murderer" Dr. Hawley Crippen as he fled from England to Canada. Two years later the life-saving role of the telegraph in the *Titanic* disaster resulted in legislation mandating that all ships holding fifty or more people must carry a permanently manned wireless station. All this media attention served to reinforce the dominant mode of the technology for the point-to-point transmission of messages.

While wireless telegraphy was in the process of being institutionalized by the telegraph companies and the government, it also began to draw the attention of men and boy hobbyists. They were attracted by the glamour associated with wireless telegraphy and by the excitement of "listening in." But mostly the amateurs were attracted by the technology itself—the sheer joy of constructing wireless "sets" and communicating their enthusiasm to like-minded individuals. By 1917 there were 13,581 licensed amateur operators in the United States, and the number of unlicensed receiving stations was estimated at 150,000.

The idea of radio broadcasting arose spontaneously in several places after World War I, although David Sarnoff (later of RCA) is often credited with the most definite proposal for a "radio music box" while he was working for the American Marconi Company in New York. Broadcasting needed an audience, and radio amateurs constituted that first audience. But for the existence of amateur operators and listeners, radio broadcasting might never have developed.

Once the first few radio stations were established, broadcasters and listeners were caught in a virtuous circle: more listeners justified better programs, and better programs enticed more listeners. Between 1921 and 1922, 564 radio stations came into existence in the United States. The flood fueled a demand for domestic radio receivers, and the radio-set industry was born. The leading firm, RCA, led by David Sarnoff, sold $80 million of radio sets in the four years beginning with 1921. Existing firms such as Westinghouse and General Electric also began to

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make radio sets, competing fiercely with start-up firms such as Amrad, De Forest, Stromberg-Carlson, Zenith, and many more. By the mid-1920s the structure of American radio broadcasting had been fully determined, and it was remarkably resilient to assaults in turn from cinema, television, satellite broadcasting, and cable.

Three key points emerge from this thumbnail history of American radio broadcasting. First, radio came from a new enabling technology whose long-term importance was initially unrecognized. Originally promoted as a point-to-point communications technology, radio was reconstructed into something quite different: a broadcast entertainment medium for the mass consumer. Second, a crucial set of actors in this transformation were the radio amateurs. They built the first receivers when there was no radio-set industry, thus enabling broadcasting to take off. They are the unsung heroes of the radio story. Finally, once radio broadcasting was established, it was quickly dominated by a few giant firms—radio-set manufacturers and broadcasters. Some of these firms were the creations of individual entrepreneurs, while others came from the established electrical engineering industry. Within a decade, the firms were virtually indistinguishable.

As we shall see, the personal computer followed a similar path of development. There was an enabling technology, the microprocessor, which took several years to be used in a product that the mass consumer wanted. The computer amateur played an important but underappreciated role in this transformation, not least by being a consumer for the first software companies—whose role was analogous to that of the radio broadcasters. And the personal computer spawned a major industry—with entrants coming from both entrepreneurial start-ups and established computer firms such as IBM.

MICROPROCESSORS

The enabling technology for the personal computer, the microprocessor, was developed during the period 1969–1971 in the semiconductor firm Intel. (Like many of the later developments in computer history, the microprocessor was independently invented in more than one place—but Intel was undoubtedly the most important locus.) As noted in Chapter 9, Intel was founded in 1968 by Robert Noyce and Gordon Moore, both vice presidents of Fairchild Semiconductor and two of the original Shockley Eight. Today, Intel has annual revenues of more than $50 billion and Noyce and Moore are legends of the American electronics industry. The microprocessor itself, however, was suggested not by them but by Intel engineer Ted Hoff, then in his early thirties.

When Intel first began operations in 1968, it specialized in the manufacture of semiconductor memory and custom-designed chips. Intel's custom-chip sets were typically used in calculators, video games, electronic test gear, and control equipment. In 1969 Intel was approached by the Japanese calculator manufacturer Busicom to

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develop a chip set for a new scientific calculator—a fairly up-market model that would include trigonometric and other advanced mathematical functions. The job of designing the chip set was assigned to Ted Hoff and his co-workers.

Hoff decided that instead of specially designed logic chips for the calculator, a better approach would be to design a general-purpose chip that could be programmed with the specific calculator functions. Such a chip would of course be a rudimentary computer in its own right, although it was some time before the significance of this dawned inside Intel.

The new calculator chip, known as the 4004, was delivered to Busicom in early 1971. Unfortunately, Busicom soon found itself a victim of the calculator price wars of the early 1970s and went into receivership. Before it did so, however, it negotiated the price of the 4004 downward in exchange for Intel acquiring the rights to market the new chip on its own account. Intel did this in November 1971 by placing an advertisement in *Electronics News* that read: "Announcing a new era of integrated electronics . . . a microprogrammable computer on a chip." The company's first microprocessor sold for about $1,000.

The phrase "computer on a chip" was really copywriter's license; in any real application several other memory and controller chips would need to have been attached to the 4004. But it was a potent metaphor that helped reshape the microelectronics industry over the next two years. During this period Intel replaced the 4004, a relatively low-powered device that processed only four bits of information at a time, with an eight-bit version, the 8008. The 8080, which became the basis for several personal-computer designs, appeared in April 1974. By this time other semiconductor manufacturers were starting to produce their own microprocessors—such as the Motorola 6800, the Zilog Z80, and the MOS Technology 6502. With this competition, the price of microprocessors soon fell to around $100.

It would not be for another three years, however, that a real personal computer emerged, in the shape of the Apple II. The long gestation of the personal computer contradicts the received wisdom of its having arrived almost overnight. It was rather like the transition from wireless telegraphy to radio broadcasting, which the newspapers in 1921 saw as a "fad" that "seemed to come from nowhere"; in fact, it took several years, and the role of the hobbyist was crucial.

COMPUTER HOBBYISTS AND "COMPUTER LIBERATION"

The computer hobbyist was typically a young male technophile. Most hobbyists had some professional competence. If not working with computers directly, they were often employed as technicians or engineers in the electronics industry. The typical hobbyist had cut his teeth in his early teens on electronics construction kits, bought through mail-order advertisements in one of the popular electronics

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magazines. Many of the hobbyists were active radio amateurs. But even those who were not radio amateurs owed much to the "ham" culture, which descended in an unbroken line from the early days of radio. After World War II, radio amateurs and electronics hobbyists moved on to building television sets and hi-fi kits advertised in magazines such as *Popular Electronics* and *Radio Electronics.* In the 1970s, the hobbyists lighted on the computer as the next electronics bandwagon.

Their enthusiasm for computing had often been produced by the hands-on experience of using a minicomputer at work or in college. The dedicated hobbyist hungered for a computer at home for recreational use, so that he could explore its inner complexity, experiment with computer games, and hook it up to other electronic gadgets. However, the cost of a minicomputer—typically $20,000 for a complete installation—was way beyond the pocket of the average hobbyist. To the nonhobbyist, why anyone would have wanted his own computer was a mystery: it was sheer techno-enthusiasm, and one can no more explain it than one can explain why people wanted to build radio sets sixty years earlier when there were no broadcasting stations.

It is important to understand that the hobbyist could conceive of hobby computing only in terms of the technology with which he was familiar. This was not the personal computer as we know it today; rather, the computing that the hobbyist had in mind in the early 1970s was a minicomputer hooked up to a teletype equipped with a paper-tape reader and punch for getting programs and data in and out of the machine. While teletypes were readily available in government surplus shops, the most expensive part of the minicomputer—the central processing unit—remained much too costly for the amateur. The allure of the microprocessor was that it would reduce the price of the central processor by vastly reducing the chip count in the conventional computer.

The amateur computer culture was widespread. While it was particularly strong in Silicon Valley and around Route 128, computer hobbyists were to be found all over the country. The computer hobbyist was primarily interested in tinkering with computer hardware; software and applications were very much secondary issues.

Fortunately, the somewhat technologically fixated vision of the computer hobbyists was leavened by a second group of actors: the advocates of "computer liberation." It would probably be overstating the case to describe computer liberation as a movement, but there was unquestionably a widely held desire to bring computing to ordinary people. Computer liberation was particularly strong in California, and this perhaps explains why the personal computer was developed in California rather than, say, around Route 128.

Computer liberation sprang from a general malaise in the under-thirty crowd in the post-Beatles, post–Vietnam War period of the early 1970s. There was still a strong anti-establishment culture that expressed itself through the phenomena of college dropouts, campus riots, communal living, hippie culture, and alternative

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lifestyles sometimes associated with drugs. Such a movement for liberation would typically want to wrest communications technologies from vested corporate interests. In an earlier generation the liberators might have wanted to appropriate the press, but in fact the technology of printing and distribution channels were freely available, so the young, liberal-minded community was readily able to communicate through popular magazines such as *Rolling Stone* as well as through a vast underground press. On the other hand, computer technology was unquestionably not freely available; it was mostly rigidly controlled in government bureaucracies or private corporations. The much-vaunted computer utility was, at $10 to $20 per hour, beyond the reach of ordinary users.

Few computer-liberation advocates came from the ranks of the student-led New Left, who commonly protested against IBM punch cards and all they symbolized. Instead, most individuals who viewed computers as tools for liberation were politically agnostic, more focused on forming alternative communities, and inclined to embrace new technology as a means to better achieve personal liberty and human happiness—what one scholar has labeled as the "New Communalists." Stewart Brand, Stanford University biology graduate turned publishing entrepreneur, became a leading voice for the New Communalists through creating *The Whole Earth Catalog.* Deeply influenced by cybernetics visionary Norbert Wiener, electronics media theorist Marshall McLuhan, and architect and designer Buckminster Fuller, Brand pressed NASA to publicly release a satellite photo of the Earth in 1966. Two years later the photo adorned the cover of the first edition of *The Whole Earth Catalog.* Publishing regularly between 1968 and 1971, Brand's catalog identified and promoted key products or tools for communal living and, in doing so, sought to help "transform the individual into a capable, creative person." The only "catalog" to ever win a National Book Award, the publication was inspirational to many personal-computer pioneers including Apple Computer co-founder Steve Jobs, who later reminisced: "*The Whole Earth Catalog* . . . was one the bibles of my generation. . . . It was a sort of Google in paperback form, 35 years before Google came along: it was idealistic, and overflowing with neat tools and great notions."

While Brand and *The Whole Earth Catalog* offered inspiration, the most articulate spokesperson for the computer-liberation idea was Ted Nelson, the financially independent son of Hollywood actress Celeste Holm. Among Nelson's radical visions of computing was an idea called *hypertext,* which he first described in the mid-1960s. Hypertext was a system by which an untrained person could navigate through a universe of information held on computers. Before such an idea could become a reality, however, it was necessary to "liberate" computing: to make it accessible to ordinary people at a trivial cost. In the 1970s Nelson promoted computer liberation as a regular speaker at computer hobbyist gatherings. He took the idea further in his self-published books *Computer Lib* and *Dream Machines,* which

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appeared in 1974. While Nelson's uncompromising views and his unwillingness to publish his books through conventional channels perhaps added to his anti-establishment appeal, they created a barrier between himself and the academic and commercial establishments. He influenced mainly the young, predominantly male, local Californian technical community.

Personal computing in 1974, whether it was the vision of computer liberation or that of the computer hobbyist, bore little resemblance to the personal computer that emerged three years later—that is, the configuration of a self-contained machine, somewhat like a typewriter, with a keyboard and screen, an internal microprocessor-based computing engine, and a floppy disk for long-term data storage. In 1974 the computer-liberation vision of personal computing was that of a terminal attached to a large, information-rich computer utility at very low cost, while the computer hobbyist's vision was that of a traditional minicomputer. What brought together these two groups, with such different perspectives, was the arrival of the first hobby computer, the Altair 8800.

THE ALTAIR 8800

In January 1975 the first microprocessor-based computer, the Altair 8800, was announced on the front cover of *Popular Electronics.* The Altair 8800 is often described as the first personal computer. This was true only in the sense that its price was so low that it could be realistically bought by an individual. In every other sense the Altair 8800 was a traditional minicomputer. Indeed, the blurb on the front cover of *Popular Electronics* described it as exactly that: "Exclusive! Altair 8800. The most powerful minicomputer project ever presented—can be built for under $400."

The Altair 8800 closely followed the electronics hobbyist marketing model: it was inexpensive ($397) and was sold by mail order as a kit that the enthusiast had to assemble himself. In the tradition of the electronics hobbyist kit, the Altair 8800 did not always work when the enthusiast had constructed it; and even if it did work, it did not do anything very useful. The computer consisted of a single box containing the central processor, with a panel of switches and lights on the front; it had no display, no keyboard, and minimal memory. Moreover, there was no way to attach a device such as a teletype to the machine to turn it into a useful computer system.

The only way the Altair 8800 could be programmed was by entering programs in pure binary code by flicking the hand switches on the front. When loaded, the program would run; but the only evidence of its execution was the change in the shifting pattern of the lights on the front. This limited the Altair 8800 to programs that only a dedicated computer hobbyist would ever be able to appreciate. Entering the program was extraordinarily tedious, taking several minutes—but as there were

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only 256 bytes of memory, there was a limit to the complexity of programs that could be attempted.

The Altair 8800 was produced by a tiny Albuquerque, New Mexico, electronics kit supplier, Micro Instrumentation Telemetry Systems (MITS). The firm had originally been set up by an electronics hobbyist, Ed Roberts, to produce radio kits for model airplanes. In the early 1970s Roberts began to sell kits for building electronic calculators, but that market dried up in 1974 during the calculator wars. Although he had toyed with the idea of a general-purpose computer for some time, it was only when the more obvious calculator market faded away that he decided to take the gamble.

The Altair 8800 was unprecedented and in no sense a "rational" product; it would appeal only to an electronics hobbyist of the most dedicated kind, and even that was not guaranteed. Despite its many shortcomings, the Altair 8800 was the grit around which the pearl of the personal-computer industry grew during the next two years. The limitations of the Altair 8800 created the opportunity for small-time entrepreneurs to develop "add-on" boards so that extra memory, conventional teletypes, and audiocassette recorders (for permanent data storage) could be added to the basic machine. Almost all of these start-up companies consisted of two or three people—mostly computer hobbyists hoping to turn their pastime to profit. A few other entrepreneurs developed software for the Altair 8800.

The most important of the early software entrepreneurs was Bill Gates, the cofounder of Microsoft. Although his ultimate financial success was extraordinary, his background was quite typical of a 1970s software nerd—a term that conjures up an image of a pale, male adolescent, lacking in social skills, programming by night and sleeping by day, oblivious to the wider world and the need to gain qualifications and build a career. This stereotype, though exaggerated, contains an essential truth; nor was it a new phenomenon—the programmer-by-night has existed since the 1950s. Indeed, programming the first personal computers had many similarities to programming a 1950s mainframe: there were no advanced software tools, and programs had to be handcrafted in the machine's own binary codes so that every byte of the tiny memory could be used to its best advantage.

Gates, born in 1955 in Seattle to upper-middle-class parents, was first exposed to computers in 1969, when he learned to program in BASIC using a commercial time-sharing system on which his high school rented time. He and his close friend, Paul Allen, two years his senior, discovered a mutual passion for programming. They also shared a strong entrepreneurial flair from the very beginning: when Gates was only sixteen, long before the personal-computer revolution, the two organized a small firm for the computer analysis of traffic data, which they named Traf-O-Data. Whereas Allen went on to study computer science at Washington State University, Gates decided—under the influence of his lawyer father—to prepare for a legal career at Harvard University, where he enrolled in the fall of 1973.

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However, he soon found that his studies did not engage his interest, and he continued to program by night.

The launch of the Altair 8800 in 1975 transformed Gates's and Allen's lives. Almost as soon as they heard of the machine, they recognized the software opportunity it represented and proposed to MITS's Ed Roberts that they should develop a BASIC programming system for the new machine. Besides being easy to develop, BASIC was the language favored by the commercial time-sharing systems and minicomputers that most computer hobbyists had encountered, and would therefore be the ideal vehicle for the personal-computer market. Roberts was enthusiastic, not least because BASIC would need a lot more memory to run than was normally provided with the Altair 8800; he expected to be able to sell extra memory with a high margin of profit.

Gates and Allen formed a partnership they named Micro-Soft (the hyphen was later dropped), and after six weeks of intense programming effort they delivered a BASIC programming system to MITS in February 1975. Now graduated, Allen became software director at MITS—a somewhat overblown job title for what was still a tiny firm located in a retail park. Gates remained at Harvard for a few more months, more from inertia than vocation; by the end of the academic year the direction of the booming microcomputing business was clear, and Gates abandoned his formal education. During the next two years, literally hundreds of small firms entered the microcomputer software business, and Microsoft was by no means the most prominent.

The Altair 8800, and the add-on boards and software that were soon available for it, transformed hobby electronics in a way not seen since the heyday of radio. In the spring of 1975, for example, the "Homebrew Computer Club" was established in Menlo Park, on the edge of Silicon Valley. Besides acting as a swap shop for computer components and programming tips, it provided a forum for the computer-hobbyist and computer-liberation cultures to meld.

During the first quarter of 1975, MITS received over $1 million in orders for the Altair 8800 and launched its first "worldwide" conference. Speakers at the conference included Ed Roberts, Gates and Allen as the developers of Altair BASIC, and the computer-liberation guru Ted Nelson. At the meeting Gates launched a personal diatribe against hobbyists who pirated software. This was a dramatic position: he was advocating a shift in culture from the friendly sharing of free software among hobbyists to that of an embryonic branch of the software-products industry. Gates encountered immense hostility—his speech was, after all, the very antithesis of computer liberation. But his position was eventually accepted by producers and consumers, and over the next two years it was instrumental in transforming the personal computer from a utopian ideal into an economic artifact.

The period 1975–1977 was a dramatic and fast-moving one in which the microcomputer was transformed from a hobby machine to a consumer product. The

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outpouring of newly launched computer magazines remains the most permanent record of this frenzy. Some of them, such as *Byte* and *Popular Computing,* followed in the tradition of the electronics hobby magazines, while others, such as the whimsically titled *Dr. Dobb's Journal of Computer Calisthenics and Orthodontia,* responded more to the computer-liberation culture. The magazines were important vehicles for selling computers by mail order, in the tradition of hobby electronics. Mail order was soon supplanted, however, by computer stores such as the Byte Shop and ComputerLand, which initially had the ambiance of an electronics hobby shop: full of dusty, government-surplus hardware and electronic gadgets. Within two years, ComputerLand would be transformed into a nationwide chain, stocking shrink-wrapped software and computers in colorful boxes.

While it had taken the mainframe a decade to be transformed from laboratory instrument to business machine, the personal computer was transformed in just two years. The reason for this rapid development was that most of the subsystems required to create a personal computer already existed: keyboards, screens, disk drives, and printers. It was just a matter of putting the pieces together. Hundreds of firms—not just on the West Coast but all over the country—sprang up over this two-year period. They were mostly tiny start-ups, consisting of a few computer hobbyists or young computer professionals; they supplied complete computers, add-on boards, peripherals, or software. Within months of its initial launch at the beginning of 1975, the Altair 8800 had itself been eclipsed by dozens of new models produced by firms such as Applied Computer Technology, IMSAI, North Star, Cromemco, and Vector.

THE RISE OF APPLE COMPUTER

Most of the new computer firms fell almost as quickly as they rose, and only a few survived beyond the mid-1980s. Apple Computer was the rare exception in that it made it into the Fortune 500 and achieved long-term global success. Its initial trajectory, however, was quite typical of the early hobbyist start-ups.

Apple was founded by two young computer hobbyists, Stephen Wozniak and Steve Jobs. Wozniak grew up in Cupertino, California, in the heart of the booming West Coast electronics industry. Like many of the children in the area, he lived and breathed electronics. Wozniak took to electronics almost as soon as he could think abstractly; he was a talented hands-on engineer, lacking any desire for a deeper, academic understanding. He obtained a radio amateur operating license while in sixth grade, graduated to digital electronics as soon as integrated circuits became available in the mid-1960s, and achieved a little local celebrity by winning an interschools science prize with the design of a simple adding circuit. Unmotivated by academic studies, he drifted in and out of college without gaining significant qualifications, although he gained a good working knowledge of minicomputers.

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Like many electronics hobbyists, Wozniak dreamed of owning his own minicomputer, and in 1971 he and a friend went so far as to construct a rudimentary machine from parts rejected by local companies. It was around this time that he teamed up with Steve Jobs, five years his junior, and together they went into business making "blue boxes"—gadgets that mimicked dial tones, enabling telephone calls to be made for free. While blue boxes were not illegal to make and sell, using them was illegal, as it defrauded the phone companies of revenues; but many of these hobbyists regarded it as a victimless crime—and in the moral climate of the West Coast computer hobbyist, it was pretty much on a par with pirating software. This in itself is revealing of how far cultural attitudes would shift as the personal computer made the transition from hobby to industry.

Despite his lack of formal qualifications, Wozniak's engineering talent was recognized and he found employment in the calculator division of Hewlett-Packard (HP) in 1973; were it not for what amounted to a late-twentieth-century form of patronage that prevailed in the California electronics industry, Wozniak might have found his career confined to that of a low-grade technician or repairman.

While Wozniak was a typical, if unusually gifted, hobbyist, Steve Jobs bridged the cultural divide between computer hobbyism and computer liberation. That Apple Computer ultimately became a global player in the computer industry is largely due to Jobs's evangelizing about the personal computer, his ability to harness Wozniak's engineering talent, and his willingness to seek out the organizational capabilities needed to build a business.

Born in 1955, Jobs was brought up by adoptive blue-collar parents. Although not a child of the professional electronic-engineering classes, Jobs took to the electronics hobbyism that he saw all around him. While a capable enough engineer, he was not in the same league as Wozniak. There are many stories of Jobs's astounding, and sometimes overbearing, self-confidence, which had a charm when he was young but was seen as autocratic and immature when he became the head of a major corporation. One of the more celebrated stories about him is that, at the age of thirteen, when he needed some electronic components for a school project, he telephoned William Hewlett, the multimillionaire co-founder of Hewlett-Packard. Hewlett, won over by Jobs's chutzpah, not only gave him the parts but offered him a part-time job with the company.

Something of a loner, and not academically motivated, Jobs drifted in and out of college in the early 1970s before finding a well-paid niche as a games designer for Atari. An admirer of the Beatles, like them Jobs spent a year pursuing transcendental meditation in India and turned vegetarian. Jobs and Wozniak made a startling contrast: Wozniak was the archetypal electronics hobbyist with social skills to match, while Jobs affected an aura of inner wisdom, wore open-toed sandals, had long, lank hair, and sported a Ho Chi Minh beard.

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The turning point for both Jobs and Wozniak was attending the Homebrew Computer Club in early 1975. Although Wozniak knew about microprocessors from his familiarity with the calculator industry, up to that point he had not realized that they could be used to build general-purpose computers and had not heard of the Altair 8800. But he had actually built a computer, which was more than could be said of most Homebrew members at that date, and he found himself among an appreciative audience. He quickly took up the new microprocessor technology and, within a few weeks, had thrown together a computer based on the MOS Technology 6502 chip. He and Jobs called it the "Apple," for reasons that are now lost in time, but possibly as a nod to the Beatles' record label.

While Jobs never cared for the "nit-picking technical debates" of the Homebrew computer enthusiasts, he did recognize the latent market they represented. He therefore cajoled Wozniak into developing the Apple computer and marketing it, initially through the Byte Shop. The Apple was a very crude machine, consisting basically of a naked circuit board and lacking a case, a keyboard, a screen, or even a power supply. Eventually about two hundred were sold, each hand-assembled by Jobs and Wozniak in the garage of Jobs's parents.

In 1976 Apple was just one of dozens of computer firms competing for the dollars of the computer hobbyist. Jobs recognized before most, however, that the microcomputer had the potential to be a consumer product for a much broader market if it were appropriately packaged. To be a success as a product, the microcomputer would have to be presented as a self-contained unit in a plastic case, able to be plugged into a standard household outlet just like any other appliance; it would need a keyboard to enter data, a screen to view the results of a computation, and some form of long-term storage to hold data and programs. Most important, the machine would need software to appeal to anyone other than an enthusiast. First this would be BASIC, but eventually a much wider range of software would be required. This, in a nutshell, was the specification for the Apple II that Jobs passed down to Wozniak to create.

For all his naïveté as an entrepreneur Jobs understood, where few of his contemporaries did not, that if Apple was to become a successful company, it would need access to capital, professional management, public relations, and distribution channels. None of these was easy to find at a time when the personal computer was unknown outside hobbyist circles. Jobs's evangelizing was called on in full measure to acquire these capabilities. During 1976, while Wozniak designed the Apple II, Jobs secured venture capital from Mike Markkula, to whom he had been introduced by his former employer at Atari, Nolan Bushnell. Markkula was a thirty-four year-old former Intel executive who had become independently wealthy from stock options. Through Markkula's contacts, Jobs located an experienced young professional manager from the semiconductor industry, Mike Scott, who agreed to serve as president of the company. Scott would take care of operational management, leaving Jobs free

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to evangelize and determine the strategic direction of Apple. The last piece of Jobs's plan fell into place when he persuaded the prominent public relations company Regis McKenna to take on Apple as a client.

Throughout 1976 and early 1977, while the Apple II was being perfected, Apple Computer remained a tiny company with fewer than a dozen employees occupying two thousand square feet of space in Cupertino, California.

SOFTWARE: MAKING PERSONAL COMPUTERS USEFUL

During 1977 three distinct paradigms for the personal computer emerged, represented by three leading manufacturers: Apple, Commodore Business Machines, and Tandy, each of which defined the personal computer in terms of its own existing culture and corporate outlooks.

If there can be said to be a single moment when the personal computer arrived in the public consciousness, then it was at the West Coast Computer Faire in April 1977, when the first two machines for the mass consumer, the Apple II and the Commodore PET, were launched. Both machines were instant hits, and for a while they vied for market leadership. At first glance the Commodore PET looked very much like the Apple II in that it was a self-contained appliance with a keyboard, a screen, a cassette tape for program storage, and with BASIC ready-loaded so that users could write programs.

The Commodore PET, however, coming from Commodore Business Machines—a firm that had originally made electronic calculators—was not so much a computer as a calculator writ large. For example, the keyboard had the tiny buttons of a calculator keypad rather than the keyboard of a standard computer terminal. Moreover, like a calculator, the PET was a closed system, with no potential for add-ons such as printers or floppy disks. Nevertheless, this narrow specification and the machine's low price appealed to the educational market, where it found a niche supporting elementary computer studies and BASIC programming; eventually several hundred thousand machines were sold.

By contrast, the Apple II, although more expensive than the PET (it cost $1,298, excluding a screen), was a true computer system with the full potential for adding extra boards and peripherals. The Apple II was therefore far more appealing to the computer hobbyist because it offered the opportunity to engage with the machine by customizing it and using it for novel applications that the manufacturers could not envisage.

In August 1977 the third major computer vendor, Tandy, entered the market, when it announced its TRS-80 computer for $399. Produced by Tandy's subsidiary, Radio Shack, the TRS-80 was aimed at the retailer's existing customers, who consisted mainly of electronics hobbyists and buyers of video games. The low price was

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achieved by having the customer use a television set for a screen and an audiocassette recorder for program storage. The resulting hook-up was no hardship to the typical Tandy customer, although it would have been out of place in an office.

Thus, by the fall of 1977, although the personal computer had been defined physically as an artifact, a single constituency had not yet been established. For Commodore the personal computer was seen as a natural evolution of its existing calculator line. For Tandy it was an extension of its existing electronics-hobbyist and video games business. For Apple the machine was initially aimed at the computer hobbyist.

Jobs's ambition went beyond the hobby market, and he envisioned the machine also being used as an appliance in the home—perhaps the result of his experience as a designer of domestic video games. This ambiguity was revealed by the official description of the Apple II as a "home/personal computer." The advertisement that Regis McKenna produced to launch the Apple II showed a housewife doing kitchen chores while in the background her husband sat at the kitchen table hunched over an Apple II, seemingly managing the household's information. The copy read:

> The home computer that's ready to work, play and grow with you. . . . You'll be able to organize, index and store data on household finances, income taxes, recipes, your biorhythms, balance your checking account, even control your home environment.

These domestic projections for the personal computer were reminiscent of those for the computer utility in the 1960s, and were equally misguided. Moreover, the advertisement did not point out that these domestic applications were pure fantasy—there was no software available for "biorhythms," accounts, or anything else.

The constituency for the personal computer would be defined by the software that was eventually created for it. At that time it was very easy to set up as a personal-computer software entrepreneur: all one needed was a machine on which to develop the software and the kind of programming know-how possessed by any talented first-year computer science student, which many hobbyists had already picked up in their teenage years. The barriers to entry into personal-computer software were so low that literally *thousands* of firms were established—and their mortality rate was phenomenal.

Up to 1976 there was only a handful of personal-computer software firms, mainly producing "system" software. The most popular products included Microsoft's BASIC programming language and Digital Research's CP/M operating system, which were each used in many different makes of computer. This software was usually bundled with the machine, and the firm was paid a royalty included in the overall price of the computer. In 1977 personal-computer software was still

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quite a small business: Microsoft had just five employees and annual sales of only $500,000.

With the arrival of consumer-oriented machines such as the Apple II, the Commodore PET, and the Tandy TRS-80, however, the market for "applications" software took off. Applications software enabled a computer to perform useful tasks without the owner having to program the machine directly. There were three main markets for applications software: games, education, and business.

The biggest market, initially, was for games software, which reflected the existing hobbyist customer base:

> When customers walked into computer stores in 1979, they saw racks of software, wall displays of software, and glass display cases of software. Most of it was games. Many of these were outer space games—*Space, Space II, Star Trek.* Many games appeared for the Apple, including Programma's simulation of a video game called *Apple Invaders.* Companies such as Muse, Sirius, Broderbund, and On-Line Systems reaped great profits from games.

Computer games are often overlooked in discussions of the personal-computer software industry, but they played an important role in its early development. Programming computer games created a corps of young programmers who were very sensitive to human-computer interaction. The most successful games were ones that needed no manuals and gave instant feedback. The most successful business software had similar, user-friendly characteristics. As for the games-software companies themselves, the great majority of them faded away. While a handful of firms became major players, the market for recreational software never grew as large as that for business applications.

The second software market was for educational programs. Schools and colleges were the first organizations to buy personal computers on a large scale: software was needed to learn mathematics; simulation programs were needed for science teaching; and programs were needed for business games, language learning, and music. Much of this early software was developed by teachers and students in their own time and was of rather poor quality. Some major programs were developed through research grants, but because of the charitable status of its institutional creators, the software was either free or sold on a nonprofit basis. As a result the market for educational software developed haphazardly.

The market of packaged software for business applications developed between 1978 and 1980, when three generic applications enabled the personal computer to become an effective business machine: the spreadsheet, the word processor, and the database.

The first application to receive wide acceptance was the VisiCalc spreadsheet. The originator of VisiCalc was a twenty-six-year-old Harvard MBA student, Daniel

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Bricklin, who thought of the idea of using a personal computer as a financial analysis tool, as an alternative to using a conventional mainframe computer or a time-sharing terminal. Bricklin sought the advice of a number of people, including his Harvard-professor supervisor, but they were all somewhat discouraging because his idea seemed to offer no obvious advantage over a conventional computer. Bricklin was not dissuaded, however, and during 1977–1978 he went into partnership with a programmer friend, Bob Frankston. In their spare time they developed a program for the Apple II computer. To market the program, Bricklin approached a former colleague from his MBA course who was then running a company called Personal Software, which specialized in selling games software. They decided to call the program VisiCalc, for *Visi*ble *Calc*ulator.

Bricklin's program used about 25,000 bytes of memory, which was about as big as a personal computer of the period could hold, but was decidedly modest by mainframe standards. The personal computer, however, offered some significant advantages that were not obvious at the outset. Because the personal computer was a stand-alone, self-contained system, changes to a financial model were displayed almost instantaneously compared with the several seconds it would have taken on a conventional computer. This fast response enabled a manager to explore a financial model with great flexibility, asking what were known as "what if?" questions. It was almost like a computer game for executives.

When it was launched in December 1979, VisiCalc was a word-of-mouth success. Not only was the program a breakthrough as a financial tool but its users experienced for the first time the psychological freedom of having a machine of one's own, on one's desk, instead of having to accept the often mediocre take-it-or-leave-it services of a computer center. Moreover, at $3,000, including software, an Apple II and VisiCalc could be bought on a departmental, or even a personal, budget.

The success of VisiCalc has become one of the great heroic episodes of the personal-computer revolution and is often, alone, credited with transforming the industry. On the whole, the role of VisiCalc has been exaggerated. Apple itself estimated that only 25,000 of the 130,000 computers it sold before September 1980 were bought on the strength of VisiCalc. Important as VisiCalc was, it seems highly likely that if it had not existed, then a word-processor or database application would have brought the personal computer into corporate use by the early 1980s.

Word processing on personal computers did not develop until about 1980. One reason for this was that the first generation of personal computers displayed only forty uppercase letters across the screen, and good-quality printers were expensive. This did not matter much when a spreadsheet was being used, but it made a personal computer much less attractive for word processing than an electric typewriter or a dedicated word-processing system. By 1980, however, new computers were coming onto the market capable of displaying eighty letters across the screen,

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including both upper and lower cases. The new computers could display text on the screen that was identical to the layout of the printed page—known as "what you see is what you get," or WYSIWYG. Previously, this facility had been available only in a top-of-the-line word processor costing several thousand dollars. The availability of low-cost printers that produced reasonable quality output, primarily from Japanese manufacturers, also greatly helped the word-processing market.

The first successful firm to produce word-processing software was MicroPro, founded by the entrepreneur Seymour Rubinstein in 1978. Rubinstein, then in his early forties, was formerly a mainframe software developer. He had a hobbyist interest in amateur radio and electronics, however, and when the first microcomputer kits became available, he bought one. He recognized very early on the personal computer's potential as a word processor, and he produced a program called WordMaster in 1978. This was replaced in mid-1979 with a full WYSIWYG system called WordStar, which quickly gained a two-thirds market share. WordStar sold hundreds of copies a month, at $450 a copy. During the next five years MicroPro sold nearly a million copies of its processing software and became a $100-million-a-year business.

During 1980, with dozens of spreadsheet and word-processing packages on the market and the launch of the first database products, the potential of the personal computer as an office machine became clearly recognizable. At this point the traditional business-machine manufacturers, such as IBM, began to take an interest.

THE IBM PC AND THE PC PLATFORM

IBM was not, in fact, the giant that slept soundly during the personal-computer revolution. IBM had a sophisticated market research organization that attempted to predict market trends, and once the personal computer became clearly defined as a business machine in 1980, IBM reacted with surprising speed. The proposal that IBM should enter the personal-computer business came from William C. Lowe, a senior manager who headed the company's "entry-level systems" division in Boca Raton, Florida. In July 1980 Lowe made a presentation to IBM's senior management in Armonk, New York, with a radical plan: not only should IBM enter the personal-computer market but it should also abandon its traditional development processes in order to match the dynamism of the booming personal-computer industry.

For nearly a century IBM had operated a bureaucratic development process by which it typically took three years for a new product to reach the market. Part of the delay was due to IBM's century-old vertical integration practice, by which it maximized profits by manufacturing in-house all the components used in its products: semiconductors, switches, plastic cases, and so on. Lowe argued that IBM should instead adopt the practice of the rest of the industry by outsourcing all the components it did not already have in production, including software. Lowe

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proposed yet another break with tradition—that IBM should not use its direct sales force to sell the personal computer but should instead use regular retail channels.

Surprisingly, in light of its stuffy image, IBM's top management agreed to all that Lowe recommended, and within two weeks of his presentation he was authorized to go ahead and build a prototype, which had to be ready for the market within twelve months. The development of the personal computer would be known internally as Project Chess. IBM's relatively late entry into the personal-computer market gave it some significant advantages. Not least, it could make use of the second generation of microprocessors (which processed sixteen bits of data at a time instead of eight); this would make the IBM personal computer significantly faster than other machines on the market. IBM chose to use the Intel 8088 chip, thereby guaranteeing Intel's future prosperity.

Although IBM was the world's largest software developer, paradoxically it did not have the skills to develop software for personal computers. Its bureaucratic software-development procedures were slow and methodical, and geared toward large software artifacts; the company lacked the critical skills needed to develop the "quick-and-dirty" software needed for personal computers.

IBM initially approached Gary Kildall of Digital Research—the developer of the CP/M operating system—for operating software for the new computer, and herein lies one of the more poignant stories in the history of the personal computer. For reasons now muddied, Kildall blew the opportunity. One version of the story has it that he refused to sign IBM's nondisclosure agreement, while another version has him doing some recreational flying while the dark-suited IBMers cooled their heels below. In any event, the opportunity passed Digital Research by and moved on to Microsoft. Over the next decade, buoyed by the revenues from its operating system for the IBM personal computer, Microsoft became the quintessential business-success story of the late twentieth century, and Gates became a billionaire at the age of thirty-one. Hence, for all of Gates's self-confidence and remarkable business acumen, he owed almost everything to being in the right place at the right time.

The IBM entourage arrived at Bill Gates and Paul Allen's Microsoft headquarters in July 1980. It was then a tiny (thirty-eight-person) company located in rented offices in downtown Seattle. It is said that Gates and Allen were so keen to win the IBM contract that they actually wore business suits and ties. Although Gates may have appeared a somewhat nerdish twenty-five-year-old who looked fifteen, he came from an impeccable background, was palpably serious, and showed a positive eagerness to accommodate the IBM culture. For IBM, he represented as low a risk as any of the personal-computer software firms, almost all of which were noted for their studied contempt for Big Blue. It is said that when John Opel, IBM's president, heard about the Microsoft deal, he said, "Is he Mary Gates's son?" He was. Opel and Gates's mother both served on the board of the United Way.

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At the time that Microsoft made its agreement with IBM for an operating system, it did not have an actual product, nor did it have the resources to develop one in IBM's time scale. However, Gates obtained a suitable piece of software from a local software firm, Seattle Computer Products, for $30,000 cash and improved it. Eventually, the operating system, known as MS-DOS, would be bundled with almost every IBM personal computer and compatible machine, earning Microsoft a royalty of between $10 and $50 on every copy sold.

By the fall of 1980 the prototype personal computer, known internally as the Acorn, was complete; IBM's top management gave final authorization to go into production. Lowe, his mission essentially accomplished, moved up into the higher echelons of IBM, leaving his second-in-command, Don Estridge, in overall charge. Estridge was an unassuming forty-two-year-old. Although, as the corporate spokesman for the IBM personal computer, he later became as well known as any IBMer apart from the company's president, he never attracted as much media attention as the Young Turks such as Gates and Jobs.

The development team under Estridge was now increased to more than a hundred, and factory arrangements were made for IBM to assemble computers using largely outsourced components. Contracts for the bulk supply of subsystems were finalized with Intel for the 8088 microprocessor, with Tandon for floppy disk drives, with Zenith for power supplies, and with the Japanese company Epson for printers. Contracts were also firmed up for software. Besides Microsoft for its operating system and BASIC, arrangements were made to develop a version of the VisiCalc spreadsheet, a word processor, and a suite of business programs. A games program, Adventure, was also included with the machine, suggesting that even at this late date it was not absolutely clear whether the personal computer was a domestic machine, a business machine, or both.

Not everyone at IBM was happy to see the personal computer—whether for home or business—in the company's product line. One insider was reported as saying:

> Why on earth would you care about the personal computer? It has nothing at all to do with office automation. It isn't a product for big companies that use "real" computers. Besides, nothing much may come of this and all it can do is cause embarrassment to IBM, because, in my opinion, we don't belong in the personal computer business to begin with.

Overriding these pockets of resistance inside the company, IBM began to actively consider marketing. The economics of the personal computer determined that it could not be sold by IBM's direct sales force because the profit margins would be too slender. The company negotiated with the Chicago-based Sears Company to sell the machine at its Business Centers and contracted with ComputerLand to retail the

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machine in its stores. For its traditional business customers, IBM would also sell the machines in its regular sales offices, alongside office products such as electric typewriters and word processors.

Early in 1981, only six months after the inception of Project Chess, IBM appointed the West Coast–based Chiat Day advertising agency to develop an advertising campaign. Market research suggested that the personal computer still lay in the gray area between regular business equipment and a home machine. The advertising campaign was therefore ambiguously aimed at both the business and home user. The machine was astutely named the IBM Personal Computer, suggesting that the IBM machine and the personal computer were synonymous. For the business user, the fact that the machine bore the IBM logo was sufficient to legitimate it inside the corporation. For the home user, however, market research revealed that although the personal computer was perceived as a good thing, it was also seen as intimidating—and IBM itself was seen as "cold and aloof." The Chiat Day campaign attempted to allay these fears by featuring in its advertisements a Charlie Chaplin lookalike and alluding to Chaplin's famous movie *Modern Times.* Set in a futuristic automated factory, *Modern Times* showed the "little man" caught up in a world of hostile technology, confronting it, and eventually overcoming it. The Charlie Chaplin figure reduced the intimidation factor and gave IBM "a human face."

The IBM Personal Computer was given its press launch in New York on 12 August 1981. There was intense media interest, which generated many headlines in the computer and business press. In the next few weeks the IBM Personal Computer became a runaway success that exceeded almost everyone's expectations, inside and outside the company. While many business users had hesitated over whether to buy an Apple or a Commodore or a Tandy machine, the presence of the IBM logo convinced them that the technology was for real: IBM had legitimated the personal computer. There was such a demand for the $2,880 machine (fully equipped) that production could not keep pace, and retailers could do no more than placate their customers by placing their names on a waiting list. Within days of the launch, IBM decided to quadruple production.

During 1982–1983 the IBM Personal Computer became an industry standard. Most of the popular software packages were converted to run on the machine, and the existence of this software reinforced its popularity. This encouraged other manufacturers to produce "clone" machines, which ran the same software and lent momentum to the increasingly dominant "PC platform." Producing clone machines was very easy to do because the Intel 8088 microprocessor used by IBM and almost all the other subsystems were readily available on the open market. Among the most successful of the early clone manufacturers was Houston-based Compaq, which produced its first machine in 1982. In its first full year of business, it achieved sales of $110 million. The software industry published thousands of

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programs for the IBM-compatible personal computer—or the IBM PC, as the machine soon became known. Based on its rapid impact, in January 1983 the editors of *Time* magazine nominated as their Man of the Year not a person but a machine: the PC.

Meanwhile, another entrepreneur, Michael Dell, incorporated production processes and sales innovations to capitalize on the PC standard.

DELL COMPUTER AND PROCESS INNOVATIONS

The "two men and a garage" creation myths of Hewlett-Packard and Apple Computer—mixing elements of fact and fiction—resonate with journalistic and public desires for tales of lone heroes doing brilliant work in isolation. William Hewlett's former garage in Palo Alto, California, is now a private museum for the company. This garage, where Hewlett and David Packard built HP's first product (an audio oscillator to test sound equipment), is frequently cited as the birthplace of Silicon Valley. And, nearly four decades after the launch of HP, the fact that Steve Jobs and Stephen Wozniak built the first Apple computer in the Cupertino, California, garage belonging to Jobs's parents only added to the "two men and a garage" mystique. Some management scholars have been quick to note that successful entrepreneurs generally worked for and developed knowledge and skills *within* firms before setting out on their own. In the computing industries there are plenty of examples of such individuals: William Norris left Sperry Rand to lead Control Data; Seymour Cray departed from Control Data to found Cray Research; and Robert Noyce and Gordon Moore resigned twice, first from Shockley Semiconductor and then from Fairchild Semiconductor, before co-founding and leading Intel. Despite such examples the cultural allure of "two men and a garage" has remained strong.

As the personal-computer industry progressed, the garage gave way to the college dorm room as the symbolic locus for IT entrepreneurial activity. Freshman Bill Gates left Harvard University to co-found Microsoft, freshman Shawn Fanning left Northeastern University to co-found Napster, and freshman Mark Zuckerberg left Harvard University to found Facebook. (Facebook is discussed in Chapter 12.)

Another freshman, Michael Dell, stands out from these other teenagers—for his University of Texas dorm room was not merely the location of early-planning and prototype design but also the initial site of product assembly. Beginning in 1983, Dell innovated buying, selling, and delivery processes that by 1999 had made Dell Computer the largest personal-computer company in the world. Necessary but not sufficient for Dell Computer's success was the emergence of the standard personal-computer platform and established networks of component and software providers.

For PC makers, competition rested heavily on price and, in time, on customizing processors, memory, and software to meet customer needs—all insights

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Michael Dell quickly understood and acted upon. While still in high school in Houston, Texas, Dell recognized that IBM was selling computers for nearly $3,000 that were made up of core components that could be purchased for around $700. He soon began to buy computer components to upgrade his IBM PC, and those he sold to friends. In 1983, as an eighteen-year-old freshman at the University of Texas–Austin, he began a business building upgraded PCs and add-on components in his dorm room to sell to local businesses. After Christmas break, he returned to Austin early to give himself time to incorporate his enterprise, PC's Limited. Through a small newspaper ad and word of mouth he was soon selling $50,000 to $80,000 worth of upgraded PCs a month, relocating the business, first, to a two-bedroom condo and, later, in May 1984, to a leased 1,000-square-foot office space in North Austin. He recognized that far greater profits could be made if his company actually built entire PCs, rather than just adding components to stripped-down computers that he bought from retailers who were overstocked and willing to sell at a discount. Early in 1985 Dell hired engineer Jay Bell to create Dell's first PC, which was based on the new Intel 80286 microprocessor—known as the 286.

Whereas rival PC producers such as Compaq sold through ComputerLand and other retailers, PC's Limited sold computers directly by mail order. Cutting out the middleman, PC's Limited often offered cheaper and better-value machines. From the start, Dell targeted the corporate market. A key to his success was allowing customers to choose their own specifications for disk drives, memory, and other features. This large-scale building of personal computers to order—a process known as mass customization—further distinguished PC's Limited from its competition. The company became Dell Computer Corporation in 1988 to take advantage of the name recognition of its famed founder.

By 1986 the company had gained extensive free publicity from building the world's fastest PC, but over time its mass-customization strategy allowed it to effectively sell computers at many different price points in the business, government, and individual consumer markets. Each market segment had a dedicated sales staff who tailored its products to customers. Indeed, direct sales solidified relationships with customers to achieve repeat business—the perfect strategy for an industry in which rapid advances in chip capacity—recall Moore's Law—resulted in forced obsolescence and product replacements in three- to five-year cycles.

Moore's Law rendered newly built computers less valuable with each passing month—an outcome that further benefited Dell Computer Corporation, whose finished products reached customers in a few weeks rather than the average of four months' wait for customers of competitors using retail sales channels. Dell Computer's direct sales and mass-customization practices also allowed it to order components on a just-in-time basis and hold little or no inventory. Similar techniques

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had been practiced by Toyota in the automobile industry, but Dell pioneered these lean production methods in the computer trade.

Dell was able to surpass competitors through process innovations, but key competitors in the United States, Europe, and Japan all achieved high-volume sales and placed downward pressures on prices as the PC became a standardized commodity. In the early 1980s Italian-based Olivetti and the Japanese-based firms Toshiba and Hitachi switched to the PC platform. Later in the decade, a global industry shakeout and consolidation occurred, largely resulting from the increasingly dominant PC standard. Dell's direct sales model also brought imitators—most prominently Gateway Computer Corporation, which offered a marketing twist by playing on its Iowa roots through shipping its PCs in white boxes with black cow spots. Dominant standards and concentration of market leadership in the late-1980s personal-computer industry heavily paralleled those of the 1930s radio industry, where a once wide-open industry with countless players evolved into a giant industry controlled by a handful of dominant firms. By far the greatest beneficiaries of the massive growth of personal computers were Intel and Microsoft. Nearly every PC built by IBM, Dell, Compaq, Olivetti, Hitachi, Toshiba, Gateway, and other clone producers contained a Microsoft operating system, and well over 80 percent of these PCs had an Intel microprocessor and Microsoft applications software.

Almost all of the companies that resisted the switch to the IBM standard soon went out of business or were belatedly forced into conforming. The only important exception was Apple Computer, whose founder, Steve Jobs, had seen another way to compete with the IBM standard: not by making cheaper hardware but by making better software.

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