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Intel Corporation: 1968–2003

In September 2000, Intel's stock market valuation peaked at $510 billion, making it one of the two most valuable companies in the world. Intel's phenomenal success was built on the microprocessor (also known as the central processing unit, or CPU), a product it invented in 1971. Intel began as a leading manufacturer of memory chips, switched to microprocessors in the 1980s, and by the late 1990s had evolved its strategy to become the main supplier of the building blocks for the Internet economy. As the company stated in its 2001 annual report:

> There's plenty of room for growth in the Internet revolution. In the next two decades, we predict ubiquitous networks worldwide, with tens of millions of servers connecting billions of PCs and other clients. All of these systems are based on silicon, much of it from Intel. We are well positioned to be at the heart of this long-term technology build-out, with innovative architectures targeted at key Internet areas. Our computing and communications products are the basic building blocks of the Internet.

By December 2002, however, the semiconductor industry was mired in its worst recession in history. Intel's sales, profits, and valuation had plummeted over the prior two years (see **Exhibits 1** and **2**). To restore growth, Craig Barrett, Intel's CEO, placed a number of bets. Most important, he believed that "innovation was the key to escaping a recession," so he continued investing in research and development (R&D) and manufacturing capacity while most of Intel's competitors cut back. In addition, Intel was pouring billions of dollars into networking and communications silicon, despite a depression in the communications industry. The obvious questions were: Would these moves restore Intel's historical performance? Would Intel be able to once again shape industry structure to become the leading building-block supplier in these new areas? Or, in the context of a worldwide technology meltdown, was Intel building a field of dreams, with factories and technologies that no one would want?

The Early Years

Robert Noyce, the coinventor of the integrated circuit, and Gordon Moore, famous for Moore's Law (the prediction that integrated circuits would double in power and halve in price every 18–24 months), left Fairchild Semiconductor to start Intel in the spring of 1968. The two founders, along with venture capitalist Arthur Rock, moved rapidly to recruit talented engineers.[1] First among them

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Professors Ramon Casadesus-Masanell and David Yoffie and Research Associate Sasha Mattu prepared this case. HBS cases are developed solely as the basis for class discussion. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective management.

was Andy Grove, a Ph.D. in chemical engineering from the University of California at Berkeley. Grove remembered having a good job working as the assistant director of R&D at Fairchild but left "to follow Moore." Soon an entire cadre of disaffected Fairchild employees joined Noyce, Moore, and Grove to become Intel's founding team.

Intel as a Memory Chip Company

Intel's early focus was building integrated circuit memory devices, an ambition shared by many Silicon Valley firms at the time. Discovered in the 1940s, *magnetic core memory*, a doughnut-shaped magnet that stored information, was a reliable form of computer memory. A few semiconductor companies had experimented with *dynamic random access memory (DRAM),*[a] a new breed of high-density memory that incorporated integrated circuits; no one, however, had been able to mass-produce DRAM at low cost. With growing demand for mainframe computers to manage accounting, payroll, and medical records, the memory market was huge.[2] Intel began experimenting with three alternative process technologies in an attempt to solve this problem, which Moore nicknamed its "Goldilocks strategy": "We decided that whichever approach came to fruition first would be mass-produced. Our multichip assembly approach was simply too hard. The three-prong circuit version of bipolar was too easy for competitors to copy, but the metal-oxide-semiconductor [MOS] transistors were just right. This was our first important technical decision that got our feet wet."

In 1970, driven by its advances in MOS process technology, Intel produced the 1103, the world's first 1-kilobit DRAM. The 1103 not only undercut the price of traditional memory, but was more cost effective to build and boasted increased performance while being smaller.[3] As a result, the 1103 became the first commercially successful semiconductor memory device and effectively replaced magnetic core memory as "the technology of choice for computer makers from 1970 onwards." Intel's 1K (1-kilobit) DRAM enjoyed two years of market dominance and generated the cash flow needed to invest in future generations of DRAM and other products.

While DRAMs were standard, interchangeable chips, the manufacturing process for DRAMs and other semiconductors was complex. In the chip industry, fixed costs were (and remain) huge (see **Exhibit 3**); every factory (also known as a fab) required a large clean room that extracted as many impurities as possible from the environment and very expensive equipment that generally had a useful life of only three years. Because of the complexity of the process, production yields—the percentage of manufactured items that met the necessary performance standards—were a significant driver of manufacturing costs. The yield would significantly increase with experience as firms identified and resolved trouble spots. Since all competitors faced similar fixed costs, especially in the early days of the industry, chip prices would ultimately depend on the shape of that learning curve and how aggressively competitors expanded capacity (see **Exhibit 4**).

In order to build a specific DRAM, many patents were necessary (having over 100 was common). Since one company could have a patent for a particular circuit and another company for a different one, the industry was driven by necessity to cross-license among established players. According to Grove, Intel's chairman: "Even though Intel was new on the block, we had enough credibility through the presence of Noyce to become part of that sharing network." This kind of "peace treaty" brokered through cross-licensing forced competitors to compete largely on price/performance while also deterring potential entrants who did not have access to this sharing network.

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[a] Technical terms are italicized. Definitions can be found in the glossary later in this case.

The Japanese The mass marketability of DRAMs brought larger competitors into the market by the mid-1970s. At the time, Intel was a small company competing against Japanese firms such as Hitachi and Mitsubishi that were multibillion dollar conglomerates. Japanese semiconductor firms were integrated into consumer electronics, computers, and telecommunications, and they heavily used their own products. They were also aided in part by abundant and cheap capital available in the relatively insulated Japanese financial markets of the era. Funds were channeled largely through bank loans, unlike the typical American semiconductor firm that relied proportionately on its own funding.[4] In addition, the Japanese semiconductor companies were much further ahead of their U.S. competitors in manufacturing, which resulted in significant cost advantages. According to Sunlin Chou, Intel's senior vice president of technology and manufacturing: "Manufacturing was clearly not our strength back in those days. The Japanese were beating us out with cost and yield. They had a much more disciplined approach to manufacturing. They were more concerned with defects and were ahead of us in terms of using statistical process control methods. We learned many things from the Japanese."

By the early 1980s, Japanese production yields for DRAMs were as high as 70%–80% in their fabs compared with 50%–60% for U.S. firms.[5] The Japanese further harnessed competitive advantage through their supplier relationships. DRAM producers such as NEC, Fujitsu, and Hitachi worked closely with Japanese equipment manufacturers to improve DRAM manufacturing machinery to increase yields. For example, Nikon's *photolithography* equipment was 10 times better than the equivalent U.S. version, but was not available in the United States until much later.[6]

Fight for generations Although Intel had gained market leadership with the introduction of the 1K DRAM, no company maintained leadership from one generation to the next. For the 4K DRAM generation, Intel went through several iterations to get the design right, while competitors such as Texas Instruments (TI) and Mostek raced ahead with a better design and low costs. By the 16K DRAM generation, Intel fell further behind in design. According to Moore, "We were a year late to the party and never caught up to the learning curve." By 1978, Intel was a full generation behind the Japanese; it was still working on the 16K DRAM while the Japanese plowed ahead with the 64K version. As early movers, the Japanese moved down the learning curve and aggressively cut prices. For example, Japanese 64K DRAMs sold for $28 in March 1980, and by April 1982 prices had dropped to $5–$6.[7] In the early 1980s, Intel strengthened its technical position when it led the industry's transition to CMOS DRAMs and introduced its 256K product generation. However, by the time Intel came up with the 1-megabit DRAM technology and design, the relevance of the DRAM business for Intel was already lost.

EPROM While many thought of Intel as a DRAM company in the 1970s, Grove explained that "DRAMs gave us fame, but EPROMs gave us riches." A special kind of read-only memory, an *EPROM* was easily programmable and could be erased with ultraviolet light. It was a product that evolved from DRAM technology, but only Intel initially produced it. EPROMs provided huge benefits for engineers who needed to store information quickly on a chip. Unlike standard ROM technology that required the data to be "burned" and then etched onto silicon wafers on the fab line (a process that took weeks or months), engineers could simply "write" data onto EPROMs in a few minutes. If the engineer made a mistake, he could shine an ultraviolet light on the circuits and reprogram the chip. Initially, Intel did not understand the value created by EPROMs and priced them competitively with standard ROM technology. Then, in an extremely bold move, Intel increased the price 100-fold. Moore commented: "We did not predict that EPROM would become a safety blanket for engineers who valued the time saved in being able to reprogram the memory easily, so we kept the price high and made a killing."

Intel had taken a methodical and quiet approach to positioning its EPROMs in the marketplace in contrast to its very public and vocal battle in the DRAM industry. The company was able to stay below competitors' radar screens for years before the Japanese, in the early 1980s, produced a similar product. "The market was diffused," noted Moore. "Until 1984, in absolute dollars and margins, EPROMs were definitely our money machine. When the Japanese got it, prices dropped by 90%." In the early 1990s, Intel moved from manufacturing EPROMs to manufacturing *flash memory* devices, derivatives of EPROM that Intel also invented. Flash memory was a nonvolatile, low-power memory that emerged as the primary memory for handheld devices. Prices were three to four times higher than those of DRAMs, but flash had much lower volume. The competition for flash memory was limited to the top four players in the industry, which had 70%–80% of the market.

Discovery of the Microprocessor

Intel invented the *microprocessor* in 1971, though it would be almost another decade before the company would see its potential application in personal computers (PCs). Busicom, a Japanese company, contracted Intel to design and build chips for its calculators, resulting in the first 4004 microprocessor. A team of Intel scientists had wanted to use microprocessors to build desktop computers, but Intel management was not convinced there was a market. According to Moore: "We never considered the microprocessor as an invention. We just felt it was integrating more stuff onto one chip. Initially we didn't even try to patent the basic microprocessor." Others, however, were more visionary. In 1977, Radio Shack and Commodore entered the desktop computer market. Micro Instrumentation Telemetry Systems (MITS) used Intel's 8-bit 8080 chip for its Altair computer kit, and Steve Jobs and Steve Wozniac, the founders of Apple Computer, used Motorola's 6502 chip in the Apple II PC.

Intel Exits DRAMs

Just as microprocessors started to gain traction for Intel, its DRAM business was hemorrhaging. By the early 1980s, Japanese semiconductor companies such as Fujitsu, Toshiba, Mitsubishi, NEC, and Hitachi had captured nearly half of the world memory market.[8] By 1984, Intel's total share in DRAMs was barely 1%, and manufacturing was restricted to one fab out of Intel's eight plants. Intel was still investing in technology development and design with the hope that it could recapture the market lead with a cutting-edge 1-megabit DRAM. The problem was, to what end? According to Grove: "We understood that to gain a 10% market share in DRAMs we would have to make a $600 million investment in a new fab. We were doomed to fail because there was industry overcapacity." Chou added, "With the 1-megabit DRAM, Intel had industry-leading technology and design. But by then our market share had dropped to such low levels, and DRAMs accounted for such a small portion of Intel's revenues, that management was forced to confront the relevance of the DRAM business. DRAM had really not been a good business for us for the whole decade."

The decision to exit DRAMs was difficult, according to Chou: "It was a challenging time for those of us involved in DRAM production. We saw top management strategically deciding to allocate more and more resources away from DRAMs, but yet not give up the business." Moore described a different sentiment: "The hard decision wasn't to exit DRAMs, it was to stay in. There was some serendipity involved because we had other things to do instead—we had microprocessors." Grove described the process as wrenching because DRAMs had been Intel's legacy and Intel was losing money for the first time since 1974. As Grove told the story,

> I remember a time in the middle of 1985 . . . I was in my office with Intel's chairman and CEO, Gordon Moore, and we were discussing our quandary. Our mood was downbeat.

> I looked out the window at the Ferris wheel of the Great America amusement park revolving in the distance, then I turned back to Gordon and I asked, "If we got kicked out and the board brought in a new CEO, what do you think he would do?" Gordon answered without hesitation, "He would get us out of memories." I stared at him, numb, then said, "Why shouldn't you and I walk out the door, come back and do it ourselves?"[9]

Nonetheless, Intel continued its production of flash memory during the 1990s and into the new millennium.

Intel as a Microprocessor Company

In the late 1970s, microprocessors were primarily used in calculators and as components in industrial controls. A limited number were used in microcomputers geared toward electronic enthusiasts, who built their machines from do-it-yourself kits provided by companies such as Motorola and MITS.[10] The Apple II, based on a Motorola processor, was the first major breakthrough. But it was not until IBM entered the market in 1981 with the PC that the market for microcomputers took off. To rush its product to market, IBM adopted an open standard that effectively made the IBM-PC *nonproprietary*. IBM hoped that an open standard would encourage software developers to write new programs for the IBM PC.[11] This decision catalyzed a massive structural shift in the computer industry. Historically, computer companies were vertically integrated, with each company producing its critical components. Starting in the early 1980s, the computer industry was becoming horizontal, whereby specialized players increasingly dominated each component layer (see **Exhibit 5**). As a result, an intense battle between Motorola and Intel ensued as they fought to be *the* microprocessor architecture.

Despite inventing the microprocessor, Intel was late out of the starting gate for the PC industry. Having lost the Apple account to Motorola, Intel was determined to catch up with the development of its new 8086 and 8088 microprocessors.[12] Intel initiated "Project Crush" in 1980, an intense marketing and sales campaign that boasted 2,500 *design wins*, and more importantly, secured the 8088 microprocessor to go into IBM's first PC. According to Grove: "The presence of IBM in the early '80s was crucial. By winning that contract, we won the whole industry design. The availability of packaged software and the market being less fragmented contributed to the growth momentum of the PC industry. This was a huge opportunity, and we took advantage of it."

By 1983, IBM had established a highly successful PC division that had grown to become a Fortune 500-sized company.[13] By 1985, it had generated $5.5 billion in revenues.[14] Buyers of IBM PCs were largely consumers and individual managers who were relatively unsophisticated and willing to pay a premium for the service, support, and compatibility they associated with the IBM brand. IBM's success catapulted Intel to the market lead in microprocessors. However, IBM had forced Intel to license its microprocessors to a dozen companies to ensure adequate supply. Intel captured only 30% of the revenues and profits.[15] For the second-generation product, the 80286 microprocessor introduced in 1983, Intel cut the number of licensees to four and initiated another intense marketing and sales campaign called "Checkmate." This led to a large number of design wins and reinforced Intel's position as the industry standard.[16]

Gaining Advantage

Requiring second-source manufacturing partners had been a necessary evil for semiconductor companies since the beginning of the industry. Moore noted that "we had to have multiple sources in CPUs to get the wins, so we set up Advanced Micro Devices [AMD], Fujitsu, Siemens, and others, but we were losing a lot of the profits." By the mid-1980s, Intel management was becoming increasingly dissatisfied with its second-source strategy. Intel's licenses called for their licensees to provide intellectual property of equal value. Yet Intel management concluded that it was "giving away" its technology to other companies, most notably AMD, and not getting fair value in return. According to Tom Dunlap, Intel's senior vice president and general counsel, "AMD's products were big, ugly, and late." In 1985, after four years and approximately $200 million in developing the 80386 (the first 32-bit processor), Intel made the bold decision to be the sole-source manufacturer for the first time. No one was certain whether computer original equipment manufacturers (OEMs) would actually buy a sole-sourced component. So Intel immediately set out to convince IBM of its new plan. "We told IBM that we won't second-source with AMD," commented Moore. "Instead, we'll build another plant in New Mexico. We thought we'd just do it ourselves, even if we don't meet market demand. This was the first time that we were the sole producers of CPUs and kept full control of the pricing."

But IBM feared that the 386 would cannibalize its midrange minicomputers. As IBM debated whether to adopt the new CPU, Compaq pioneered the first 386 PC. To Intel's delight, the 386 was an instant success; computer users were willing to pay a premium for the additional performance. The average selling price of the 286 chip was $40, while the 386 sold for $150.[17] It also marked the first time that a PC clone, rather than IBM, had set the new performance standard.[18]

Becoming Proprietary

Similar to building DRAMs, building microprocessors required many patents. Unlike with DRAMs, however, Intel was well ahead of its competition in intellectual property. Intel's wealth of trade secrets in design and production as well as patents resulted in substantial negotiating power in its cross-licensing agreements. In addition, microprocessors had a microcode—a software code found inside the microprocessor—that was copyrighted. Intel adamantly protected its intellectual property rights. In one landmark case, Intel sued NEC for copying its microcode, and the court found that microcode was copyrightable as a computer program and consequently could not be copied. (See **Exhibit 6.**)

Intel's decision to sole-source the manufacturing of its 386 microprocessor was fiercely challenged by AMD, which had been a second source for Intel since the mid-1970s. A legal battle ensued that lasted eight years and cost hundreds of millions of dollars.[19] In 1994 the courts ruled in favor of AMD, giving it the rights to Intel's 386 microcode.[20] When the battle spilled over to Intel's 486 microprocessor (a faster and improved version of the successful 386), Intel prevailed. By the mid-1990s, both companies were fatigued by endless hours in the courtroom. According to Dunlap:

> In 1995, we negotiated a settlement where AMD could ship the 486 with royalties but they couldn't copy anymore in the future. They had to have completely different codes and chipsets. This marked a big separation between AMD and Intel. By the Pentium generation, AMD couldn't get any trade secrets and couldn't copy our microcode, so our products developed quite differently.

Intel's Challenges in Microprocessors

Alternative Microprocessor Designs

RISC versus CISC One of the biggest perceived threats to Intel came in the late 1980s with the emergence of reduced instruction set computing, or RISC. Two alternative architectures were used in designing microprocessors: the complex instruction set computing (CISC) architecture that Intel had used for its X86 line of CPUs, and the RISC architecture, which involved fewer transistors to achieve the same result.[21] Computer systems and software that used CISC architecture were not compatible with RISC-based systems, and vice versa.

RISC processors had originally nestled themselves into a high-priced, high-performance niche. By the late 1980s, RISC processors were becoming cheaper to produce, and the emerging concern was that RISC's simpler architecture and better performance would eventually displace the traditional CISC architecture that dominated the PC environment.[22] Although the huge volume of software available for the X86 standard mitigated any immediate danger from RISC, the price/performance potential of RISC was a real threat. Microsoft was a particularly strong voice in advocating the advantages of RISC.[23] Microsoft also initiated the formation of Advanced Computing Environment (ACE), a group that consisted of 21 different companies, including Compaq and Dell, to further encourage this architectural transition.

Intel found itself in a potentially awkward position in 1989. While Intel prepared to launch its new 486 processor, it also planned to launch simultaneously a powerful RISC-based chip, the i860. In effect, Intel was hedging its bet. If RISC took off, it would have a powerful contender, but it would continue to play in CISC. The problem was that Intel found its resources divided between two architectures, which put significant pressure on its internal sales, marketing, and technical support efforts. Fortunately for Intel, the debate quickly subsided. Intel chose to back the 486, positioning the i860 as a niche product for specialized uses. At the same time, few consumers were willing to junk their installed base of applications for modest gains in performance. The threat from RISC subsided over the first half of the 1990s because the perceived performance advantages of RISC largely disappeared as Intel incorporated techniques used by RISC to improve the Pentium processor. In hindsight, Grove questioned Intel's temptation to have ever switched architectures, while Moore felt that the debate was essentially a "major press battle and not a real technological one."

Customers

Intel's immediate customers were the OEMs, which marketed finished computer systems. OEMs built and sold PCs assembled from five widely available standard components: microprocessors, *motherboards*, memory, peripherals, and operating systems. Depending on the configuration of the system and the stage in the product life cycle, the microprocessor could account for 10%–20% of the total manufactured costs of a PC.

Intel had a complex relationship with its customers. First, the company initiated an end-user advertising program. Second, Intel vertically integrated into the design and manufacture of subsystems and full systems. And third, customers often complained about Intel as a sole source, especially when it allocated supplies of newly launched chips in the face of tight capacity constraints.

Intel Inside In 1990, Dennis Carter, a Harvard MBA and head of corporate marketing, launched a highly controversial program both inside and outside Intel. Called the "Red X" campaign, it featured national full-page ads with a big 286, covered by a spray-painted red X. The following page asked consumers why they should buy a 286 (which was largely being sold by AMD at the time) when they could buy a 386SX for the same price. Surprising to some, demand for 386-based machines almost immediately exploded.

A year later, Carter took end-user branding to the next step with the "Intel Inside" campaign. "Intel Inside" involved setting up a co-op fund that set aside a percentage of the price from Intel's microprocessor sales to reimburse up to half of the participating OEMs' advertising costs. In exchange, OEMs were required to use the "Intel Inside" logo in their advertisements, as well as the "Intel Inside" sticker on their products indicating that the Intel processor was indeed inside. According to Carter:

> We rolled out "Intel Inside" in July of 1991. The point was that we wanted a fresh new user-friendly look and feel to Intel. I initially visited three OEMs—Dell, NCR, and IBM—to get a feel for what they thought of the campaign. Dell was incredibly positive and loved the co-op dollars. NCR was favorable. IBM was a little more complex. IBM's management liked the idea, but their advertising agency, who had already established a successful track record, refused to add the "Intel Inside" logo to their advertisements. All in all, we got a good start—we ended up signing 300 OEMs right off the bat.

Between 1990 and 1993, Intel spent over $500 million launching the campaign.[24] In addition to the co-op dollars, Intel invested in some TV ads that explained why the microprocessor was important for end users in their purchasing decisions. Despite growing success, there was internal resistance to "Intel Inside." Carter commented: "The only supporters at the executive level for 'Intel Inside' were Andy, the head of sales, and myself. For a few years, the vast majority of Intel executives thought it was a huge waste of money." There was also some animosity from some of Intel's key customers, particularly Compaq. At a conference in Barcelona in 1994, Compaq's CEO at the time, Eckhard Pfeiffer, summarized his company's position: "I'd like to make three points to Intel: don't impose products and prices on us, don't be our competitor, and don't use Intel Inside."[25]

By the late 1990s, "Intel Inside" had been widely adopted, even by Compaq. "Intel Inside" had become one of the world's most recognized brands. Yet in 2000, there was less willingness to pay a premium for the brand, especially among price-sensitive consumers. Carter and his successor, Pam Pollace, however, remained optimistic that the brand equity of "Intel Inside" could be retained. "'Intel Inside' is not tarnished or tainted," Carter said.

Forward integration In the early 1970s, Intel formed a systems group responsible for the development of a series of computer-based instruments that stimulated and tested Intel-based products.[26] These systems helped the engineers at OEMs to design computers that used Intel microprocessors. In addition, Intel Systems also invested in developing a line of supercomputers that used up to 128 microprocessors for the purpose of processing difficult calculations at extreme speeds for niche industry sectors.[27]

By the mid-1980s, the largest segment of Intel Systems' business involved microcomputer products for OEMs.[28] For example, Intel introduced a desktop computer in 1987 based on the 80386, which was sold to OEMs without a screen, keyboard, or brand.[29] Between 1987 and 1989, well-known computer companies including Prime, AT&T, and Unisys bought Intel systems and rebranded them with their own name.[30] When other customers complained that Intel was helping their competition, Intel exited the low-margin complete-system business in the early 1990s but continued to sell motherboards and other computer add-on products to OEMs such as Dell and Hewlett-Packard and in the "white box" channel.

Allocation of new products in short supply During the introductory phase of any new chip, it was typically available in short supply. New microprocessors took time to ramp up production to full capacity, and PC makers were usually anxious to get hold of leading-edge microprocessors. As a result, Intel had to develop mechanisms to balance the supply and demand.

New-generation chips were generally priced at a premium to limit demand. As production capacity increased and costs declined, the price would be quickly scaled down to stimulate consumption in the mass market. It was not unusual to see price drops of 30%–50% in less than one year (see **Exhibit** 7). Intel also made a concerted effort to speed the ramp-up of its new processors. For example, it had taken four and a half years for the 386 to achieve a 25% share of the X86 market, but only three and a half for the 486 chip and still less time for each generation of Pentium.[31] Nonetheless, the demand for new chips frequently exceeded new supply, leading Intel to allocate its chips preferentially to its best customers.

End users In 1994, while testing their new Pentium microprocessor, engineers found a design flaw. Historically, all CPU manufacturers had found obscure problems in their chips, but most "errata," as they were known, were so rare that they were hardly ever reported. In this case, Intel engineers calculated that for the average Pentium owner, a wrong answer would arise once every 27,000 years.[32] In November of 1994, however, there was a media storm when word leaked out that a math professor found a "bug in the Pentium."[33] Intel's initial response was to tell users not to worry; CPUs always had flaws, but they were of no concern. As the uproar grew, Intel announced that it would replace chips only for individuals who used their computers for heavy-duty mathematical computations. "Our replacement policy was based on our assessment of the problem," Grove said.[34] Then pandemonium struck when IBM announced that it would halt shipment of Pentium-based computers because they were unreliable. Faced with an onslaught of replacement demands from customers, Intel quickly decided to honor every request. Fixing the Pentium flaw cost $475 million, the equivalent of a half year's R&D budget at the time.[35]

Suppliers

When Intel became the leader in capital expenditures in the semiconductor industry in the early 1990s, it became the 800-pound gorilla for semiconductor equipment suppliers. Intel used its buying leverage to push suppliers to move faster to next-generation products. According to Sunlin Chou (senior VP of technology and manufacturing):

> Working with suppliers is key to maintaining our technology leadership position. We will continue to invest with suppliers to develop cutting-edge technology in return for privileged, early access to the most advanced capabilities. We ask not for custom solutions, but standard solutions that will eventually be used by the industry at large. We just want first dibs in getting it.

Intel found this approach particularly advantageous with smaller equipment suppliers and projects where it might be the sole investor, thereby securing its privileged access to leading-edge equipment. However, for a major, expensive program such as the development of extreme ultraviolet (EUV) lithography equipment, Intel formed a consortium that included several other major chip makers to fund the technical work and to reach the critical mass needed to gain industry acceptance and support for the technology. When possible, Intel sought to have dual suppliers as a means of securing quality and timeliness of the equipment.

Complementors

Microsoft When the computer business moved toward a horizontal structure, the standards that defined a PC were no longer in the hands of a single player but rather shared by Intel and Microsoft.[36] According to Frank Ehrig, the former liaison between Intel and Microsoft and Barrett's technical assistant: "We mutually know that the PC market and platform innovation rests collectively on both our shoulders." Intel senior management would routinely meet with Microsoft senior management to coordinate processor and operating system development. Teams at various levels of both companies also met regularly to collaborate on designs.

Yet the symbiotic nature of Microsoft and Intel's relationship was not void of conflict. Software production had historically lagged behind hardware design. Intel's 32-bit microprocessor, for example, waited 10 years before Microsoft produced a 32-bit operating system (Windows 95). From Intel's perspective, complementary software was critical for driving demand. Ehrig commented:

> Intel is always trying to innovate on hardware platform and, thus, always needs software. When software lags, it creates a bottleneck for Intel. Microsoft, on the other hand, wants to serve the installed base of computers in addition to demand for new computers. Therefore, a natural conflict exists between both companies. In addition, the question always remains—who will get the bigger piece of the pie? The success of one is seen as ultimately taking money away from the other.

Other independent software vendors In addition to its ongoing relationship with Microsoft, Intel aggressively courted independent software vendors to write software applications for their leading-edge processors. Without exciting new applications that took advantage of Intel's performance, there would be no compelling need for consumers or corporations to upgrade. When Intel launched its MMX multimedia processor in 1996, for example, Intel spent $100 million to pay game writers and other software vendors to accelerate their product plans and to take advantage of the multimedia instructions in the new chip. The result was dozens of programs available at the date of launch that ran faster and better on the MMX processor. Similarly, in preparation for its new 64-bit Itanium processor, Intel formed a venture fund of $250 million with other investors to facilitate the development of new 64-bit software that would uniquely leverage the Itanium's advantages.

Intel Capital To develop a microprocessor, Intel would often outsource bits and pieces of technology, such as an algorithm, from very small companies. Intel often invested in these companies to ensure the work was completed in a timely way. The formation of Intel Capital (IC) in the early 1990s was an attempt to systematize this process. According to Les Vadasz, president of IC, "We realized that we alone don't create the market. We need complementors to help develop and create an ecosystem. This was the genesis of Intel Capital: the creation of a market ecosystem and the development of complementors to drive the system."

IC was not a typical venture capital firm; its strategy was to invest in companies that fit strategically into Intel's business strategy as well as offered a financial return. Vadasz explained, "A VC might invest in a Web application that operated in the Sun environment, but we would not. We look for opportunities that tie into Intel's business strategy." One example was an investment in AsiaInfo during the third quarter of 1999. The company was an equipment supplier to China Telecom. According to Vadasz:

> After the investment, we made our first inroads in the telecom applications market in China for Intel Architecture servers. We put technical and marketing resources into the relationship, added a board observer, and helped them port their software to our hardware. We also participated in many joint marketing programs. AsiaInfo then went public in Q1 2000, and by the end of 2001, we had recorded significant cash gains from the IPO.

Intel believed that it added value beyond financial support by making introductions worldwide and giving start-ups opportunities to interact with Intel engineers. In November 2002, IC's portfolio consisted of nearly 400 companies in communications (broadband and wireless, cellular and handheld, network and storage, and optical) and computing (client, corporate technology, semiconductor design and manufacturing, enterprise software, and server platform). IC received over 5,000 unsolicited requests per year and 15,000–20,000 during the industry's peak. And despite the downturn in 2000–2002, IC had returned several billion dollars in cash to Intel.

By year-end 2002, IC had investment activities focused on all significant business initiatives that the company pursued. For example, through its 64Fund (established in 1999), the investment focus was to accelerate the market ecosystem development of its Itanium product family. And in October 2002 the company targeted $150 million through its Intel Communications Fund on Wi-Fi technologies and services in order to accelerate the market ecosystem for mobile computing.

Antitrust

During the 1990s, the Federal Trade Commission (FTC) investigated Intel three times for possible antitrust violations. The FTC explored competitors' complaints that Intel preferentially allocated chips in short supply.[37] Critics had also claimed that Intel engaged in "tying," where the purchase of one product was tied to the purchase of a microprocessor.[38] Competitors further complained that Intel was unfairly using the litigation system to drag out cases until the window of opportunity for competitors' products was severely limited or in some cases completely gone.[39] Finally, the FTC explored whether Intel was using its trade secrets inappropriately in negotiations with customers. The FTC dropped its first two investigations against Intel, and the two sides agreed to a compromise consent decree in 1999 regarding Intel's use of trade secrets. According to General Counsel Dunlap, "We've been exceedingly careful on antitrust. We work very hard not to misuse our intellectual rights while still enforcing them. We don't have any barriers for competitors, just a few speed bumps that people have to go around."

Intel as a Builder of the Internet: The Barrett Era

Throughout the 1980s and 1990s, the PC market experienced spectacular growth. Ultimately, though, Intel management understood that growth would slow. By the late 1990s, analysts were predicting the death of the PC and growing downward pressure on component prices.[40] With the emergence of potential substitutes such as personal digital assistants (PDAs), network computers, smart phones, and other such wireless and handheld devices in the late 1990s, analysts expected declining worldwide PC shipments as well as declining worldwide microprocessor revenues (see **Exhibit 8**).

Anticipating the need for new markets outside of PCs, Intel's new CEO, Craig Barrett, pursued an aggressive strategy to build new businesses. Barrett, a Ph.D. in materials science and former professor at Stanford University, joined Intel in 1974. He was named chief operating officer (COO) in 1993, president in 1997, and CEO in March 1998, succeeding Grove. Barrett spent roughly $12 billion on acquisitions and internal ventures during his first three years as CEO, pushing Intel into new markets such as networks, wireless, communications, and online services. To reflect the change in strategy, Barrett also changed the corporate mission statement for the first time in 15 years. In 1999, Intel went from "being the preeminent supplier to the new computing industry worldwide" to "being the preeminent building-block supplier to the worldwide Internet economy." Barrett explained:

> The PC was at the center of computing during the 1990s, but if you look at the next decade, it is the Internet. The PC is still very important in the Internet era, but there are lots of other things that are important as well. People are going to access the Net off their cell phones, and more cell phones are sold today than PCs. Networking is becoming more important, whether it's in the home, small business, or enterprise. If you want to be involved in this new era, you have to look for the new growth opportunities. That's exactly what we're trying to do.[41]

Consistent with Intel's new mission, Barrett reorganized the company into four areas: client platforms, which included desktop and mobile microprocessors; server platforms; cellular and wireless, which produced chips for the integration of data and voice; and communications and networking, which designed chips used in modems, network interface cards, switches, and routers. In each of these arenas, Barrett was making big investments to reenergize Intel's growth. If Barrett continued investing at his current rate, Intel would spend almost $15 billion on capital additions and as much as $12 billion in R&D from 2002–2004. While most of the competition was cutting back, Barrett was betting that Intel's strong balance sheet, manufacturing prowess, and capabilities in circuit design could distance Intel from the field.

Client Platforms

Microprocessors and the architectural systems of the PC were generating approximately 75% of Intel's revenue and most of its profit, remaining Intel's core business in 2002. But rising performance, falling prices, and renewed competition from AMD offered complex challenges.[42]

Throughout its history, Intel relentlessly pursued Moore's Law, doubling the number of transistors on its CPU every 18 months (see **Exhibit 9**). By increasing wafer sizes, shrinking transistor sizes, and decreasing the time and cost of production, Intel hoped to stay ahead of the competition. In the late 1990s, however, Intel began to see serious challenges from AMD. In 1999, AMD introduced its Athlon processor—a CPU it bought with its acquisition of NexGen for $800 million. Not since the early 1990s had AMD come so close to matching Intel's CPU performance. Then in a major blow to Intel's prestige, AMD introduced the 1-gigahertz (GHz) Athlon microprocessor three days ahead of Intel in March 2000. This was the first time AMD could claim a lead in performance, even if it was only between Friday and Monday. Industry analysts observed: "Intel is not used to anyone being able to compete with them on performance. . . . Intel has never had a competitor like this." Intel executives responded: "They are our most accomplished competitor; you've got to give them credit for that. . . . The worst thing Intel can do is to take AMD lightly, and we don't."[43]

In response to AMD's inroads, Intel launched an aggressive campaign to drive one generation ahead of AMD on all benchmarks. A significant percentage of Intel's capital and R&D spending was pushing Intel 12–18 months ahead of AMD in process technology. In addition, Intel focused on providing products for all segments of the market to avoid leaving any holes for AMD to fill. The company aggressively segmented its 32-bit Pentium products to cover a wide price/performance range. For example, Intel created a fighting brand, called the Celeron processor, for sub-$1,000 systems and a new high-end brand, called Xeon, with more than 10 varieties of Xeon processors for servers and workstations.[44] Pricing for each of these microprocessors reflected both cost and customer-value considerations. According to Louis Burns, vice president of Intel's Desktop Platforms Group: "We have the following system price points: the first is value based, lower prices for higher volumes. The second is mainstream where really the volume is shipped, and third is the high-performance segment. Differences in yields meant that the cost of a Celeron for the value-based segment was much lower than the cost of a CPU for the high-performance category."

Nonetheless, from 2000–2002, average prices for microprocessors continued to fall, even though CPU performance improved with Moore's Law. This deflationary trend challenged Intel's historical revenue. While Intel successfully pulled a generation ahead of AMD in 2002 and AMD chips were largely found in the price-sensitive consumer segment, the most pressing issue was whether customers would pay for the added value of new microprocessors. Barrett argued that this strategy would work: "Even if we raise performance while lowering ASPs,[b] the important piece is that we are still driving technology ahead and forcing competition to innovate."

Intel was also gambling that it could change the rules of the game in 2003 and beyond. In the mobile PC domain, Intel's microprocessors had significant advantages over AMD's. In 2002, Intel had roughly 89% market segment share in mobile CPUs. Anand Chandrasekher, vice president of Intel's Mobile Platforms Group, explained:

> The mobile processor is different from the desktop processor because mobility increases the importance of size, heat, noise, and battery life. There are two different design approaches. The first is to simply take the desktop microprocessor design while encasing it into a thermal envelope. This is the equivalent of taking a 60-watt bulb down to 30 watts. The other option is to redo the whole architecture for mobile processing. We have heavily invested in the latter.

The mobile market primarily targeted the corporate environment, where buyers were typically more technically literate and less price sensitive. To stimulate demand and create a higher willingness to pay, Intel was betting that it could redefine microprocessor performance measures. Rather than aim for more gigahertz, Intel would introduce in 2003 an entire system (CPU, chipsets, and other functions) that would hopefully perform "better" (longer battery life, seamless wireless networking, etc.), even if it was not the fastest CPU. Pollace, head of worldwide marketing, argued: "In the past, we sold performance. Now the question is, what else? Intel will continue to innovate in product and process, but we need to innovate on the architectural level."

Server Platforms

A server is a computer on a network that manages network resources such as traffic, database queries, and file storage. Intel had successfully entered the market for workstations and entry-level servers with its 32-bit Xeon processor in 1998. A Xeon CPU sold for up to 10 times the price of a mainstream Pentium. While servers represented a small percentage of Intel's business, Intel spent 50% of its development dollars on the server and workstation segment in 2002. Mike Fister, senior vice president of Intel's Enterprise Platform Group, justified the value of this investment: "We are the technological seeding ground for what waterfalls down to the PCs, PDAs, and cell phones." Indeed, many of the innovations pioneered by the server group found their way into mainstream processors within a few years. Most of Intel's efforts went to the high-end server segment that ran corporate data centers. To compete with Sun Microsystems and IBM in this space, Intel had developed its high-performance *64-bit* Itanium™ processor. Built in collaboration with Hewlett-Packard, the Itanium had significant performance advantages in late 2002. Nonetheless, Itanium had been plagued with problems. It was three years late to market, shipped only modest volumes, and sold for $200–$300 more than a Xeon, even though it ran existing software slower. To take advantage of Itanium's performance, software had to be rewritten. Fister made the positive argument that Itanium was "gaining momentum. . . . The number of sold Itanium units is tiny, but this is an architecture that is going to be around for at least two decades, and we are on the historical S-curve of adoption." Observers wondered if the low availability of Itanium software would hinder its deployment. Fister framed the delays as a "blessing in disguise" since they gave software developers more time to develop Itanium software.[45]

One of the biggest challenges for Fister was expected to emerge from AMD in the second quarter of 2003. AMD had announced its own 64-bit chip, which was not as powerful as Itanium but was expected to run existing software faster. While Intel had carefully segmented its markets among

[b] Average Selling Price.

32-bit Celeron for the low-end consumer PC market—the 32-bit Pentium for the mass PC market, 32-bit Xeon for the low- and mid-range corporate server and workstation markets, and 64-bit Itanium for the high-end corporate server market—AMD's strategy was to offer customers improved 32-bit performance with some (but not all) of the advantages of a 64-bit CPU.

Cellular and Wireless

According to International Data Corporation (IDC), a market research firm: "Wireless access is the Second Coming of the Internet."[46] The wireless Web allowed people to access the Internet from cell phones, handheld computers, and other portable devices.[47] In 2002, approximately 400 million mobile cell phones were sold in the world. Cell phone users primarily subscribed to voice-only services, creating a huge potential for data services such as wireless e-mail. In the late 1990s, the leading wireless companies had introduced data networks that allowed cell phone users to pull information from the Web, but the infrastructure itself had many constraints.[48] The initiation of new services including 2.5G (e.g., GPRS) and 3G wireless networks promised up to a 200-fold improvement in data rates.[49] According to Ron Smith, senior vice president and general manager of the Wireless Communications and Computing Group: "The key is network deployment and applications in our ecosystem. We can only really grow to the extent that this is deployed."

The wireless data and communications semiconductor competition was still quite fractured in 2002, with Intel holding 8% of the market and its strongest competitor, TI, at a 14% market share. Semiconductor companies were battling to develop a microprocessor architecture that would become the industry standard for cellular and handheld devices. Smith believed that "we have to win the architectural battle with TI." While TI hoped to win by leveraging its strong position in digital signal processors (DSPs), Intel's strategy was to combine its leading position in flash memory, which was already used in most cell phones, and XScale, a derivative of the ARM architecture used in 80% of all phones. There were many ARM licensees, including Motorola and Samsung; however, XScale was a proprietary derivative created by Intel that combined improved low voltage, high performance, and multimedia for wireless devices, with a core architecture that could scale up to speeds of 1GHz. According to Smith:

> Our XScale architecture is the industry leader in performance at the low-power range. We really have to be conscious of power in the wireless mobile; we can't just focus on performance. Over time, XScale will also take advantage of the tools and software written for Intel Architecture. The combination of performance, low power, and the best software tools will be our competitive advantage.

XScale was part of Intel's Personal Internet Client Architecture (PCA). Intel believed that to keep up with the convergence of wireless phones and handheld digital devices, the development of hardware and software had to be able to occur along separate paths. Intel PCA decoupled the applications subsystem from the communications subsystem. The company hoped that this separation would help speed the development and deployment of wireless Internet devices, applications, and services. By year-end 2002, Intel PCA enjoyed wide industry support, with companies such as ATT Wireless, IBM, Sharp, Sony, and Samsung developing products optimized for PCA.

Communications and Networking

Despite a three-year recession and meltdown in communications equipment, Sean Maloney, executive vice president of the Intel Communications Group, offered a positive outlook: "Our overall industry perspective is that Internet traffic growth has doubled every year for the last four to five years. Despite the recession, there is no shortage of humans who want to communicate." Intel felt that communications silicon would be a major strategic growth opportunity and wanted to provide the industry with standard building blocks through Internet Exchange Architecture (IXA), an umbrella term for network processors and other components that allowed for more mass-produced, lower-cost, and interchangeable devices.[50]

Throughout the 1990s, the communications and networking industry was highly fragmented, with no dominant incumbents. The industry was essentially vertical, with individual companies producing everything from microprocessors and other hardware to complementary software. Intel was confident that the industry would transform itself from vertical to horizontal and wanted to see its chips as the industry standard.[51] Paul Otellini, Intel's president and COO, noted:

> There were three generational transformations: the mainframe, the PC, and converged computing and communications devices with anytime/anywhere capabilities. These shifts complement Intel's history in memories, microprocessors, and now communication. The question is whether we can use our strength in silicon microprocessors to become a force in communications.

One of Intel's biggest communications investments was to drive for a leading position in a new technology called Wi-Fi. Also known as 802.11, Wi-Fi was an industry standard for wireless broadband networks that worked over a few hundred feet at very high speed (11 megabits). According to Maloney, "The browser was the long-awaited bride for the microprocessor. Ten years later we have a technology with equivalent significance. Wi-Fi will connect all industries that want to play in the Internet."

Ironically, Intel management believed that the recession would stimulate a change in industry structure that would work to Intel's advantage. Despite a large number of incumbent competitors (see **Exhibit 10**), ranging from Broadcom to Agere (the former chip subsidiary of Bell Labs), Maloney argued that Intel's manufacturing expertise, deep pockets, and commitment to communications were a winning strategy: "There is a lot of carnage in this industry. . . . Component suppliers such as Intel are investing just as OEMs cut their R&D by 50%." Grove was similarly confident but cautious about the environment:

> The meltdown of the communications industry is a great opportunity for us since Nortel, Lucent, and Alcatel have already lost half of their technical staffs. Intel is making big bets on capital investment in an economic downturn. From a strategic standpoint we can build a gap in performance with advanced technology, but our main challenge is to keep ourselves ready to be the technical supplier of the Internet. We might have to wait for this opportunity for another five to seven years. Our challenge is that we have the right strategy and right technology, but how do we stay in a nonhemorrhaging state for an indefinite period of time?

Implementation Problems

During 1999 and 2000, Intel suffered from a series of embarrassing implementation errors that opened the door to competition and, even worse, cast doubts as to whether Intel had the capabilities to compete effectively in these more competitive new businesses.[52] The largest problems included capacity shortages, which drove some customers to AMD; various product recalls; product delays; and cancellation of announced products. Some of these problems could be attributed to technical miscalculations. For example, Intel bet on a technology called RDRAM from Rambus. Intel initially built its next-generation CPUs to require RDRAM. But as Barrett conceded: "We made a big bet on Rambus, and it did not work out."[53] During 2000, Intel began to retreat from exclusive reliance on

Rambus, yet many of its product problems were connected to that transition.[54] During the same two years, some of Intel's diversification strategy seemed to depart too far from its core. Several of Intel's acquisitions and new business ventures failed, at the cost of several billion dollars. During 2001 and 2002, Intel retrenched; it shut down businesses ranging from Web hosting, network switching, and network appliances to Intel consumer products. To avoid a recurrence of these problems, CEO Barrett introduced a back-to-basics program to achieve operational excellence. "Ninety-nine percent of our projects have been out on time or ahead of time in 2002," explained Barrett. Although crisp execution seemed back on track, Intel's prior mistakes made the company appear more vulnerable than any time in the last 15 years. Reflecting on Intel's track record in the late 1990s, Barrett noted:

> We were naïve. We got caught up in the dot-com era, which gave a much rosier picture of high tech and especially communication. We were not as realistic in our assessment of our immediate opportunities. We are now back to our core competencies as the foundation for our business models, and we have refined our selection of businesses based on a better business model. Changes in the environment have been greater than changes within Intel.

The Path Forward

Intel's critics felt that Intel had spread its resources too thinly between the maintenance of its lucrative microprocessor business and its ambitious pursuit of new business developments. To ensure that the company did not get distracted again, Intel appointed Otellini as the new COO to be primarily in charge of Intel's clients, servers, and communications businesses. This allowed Barrett to concentrate most of his efforts on developing Intel's strategic long-term direction and new business areas. Barrett's goal for 2003 was to return Intel to double-digit annual growth, with a greater percentage of this growth to come from Intel's new business areas rather than from the traditional client microprocessor business. Barrett believed that microprocessors would continue to grow, but he wanted communications and networking to provide the growth engines of the future. Barrett discussed the assumptions underlying his ambition:

> The Internet continues to build out around the world: the client part, the network connectivity part, and the server/data farm part. We provide the essential building blocks in all three of these areas. The convergence of computing and communications is the major growth driver of the Internet, and we are in both. This gives us an advantage, especially because of our strength in computing. We can grow faster than our competition using the advantage we derive from our span of competencies.

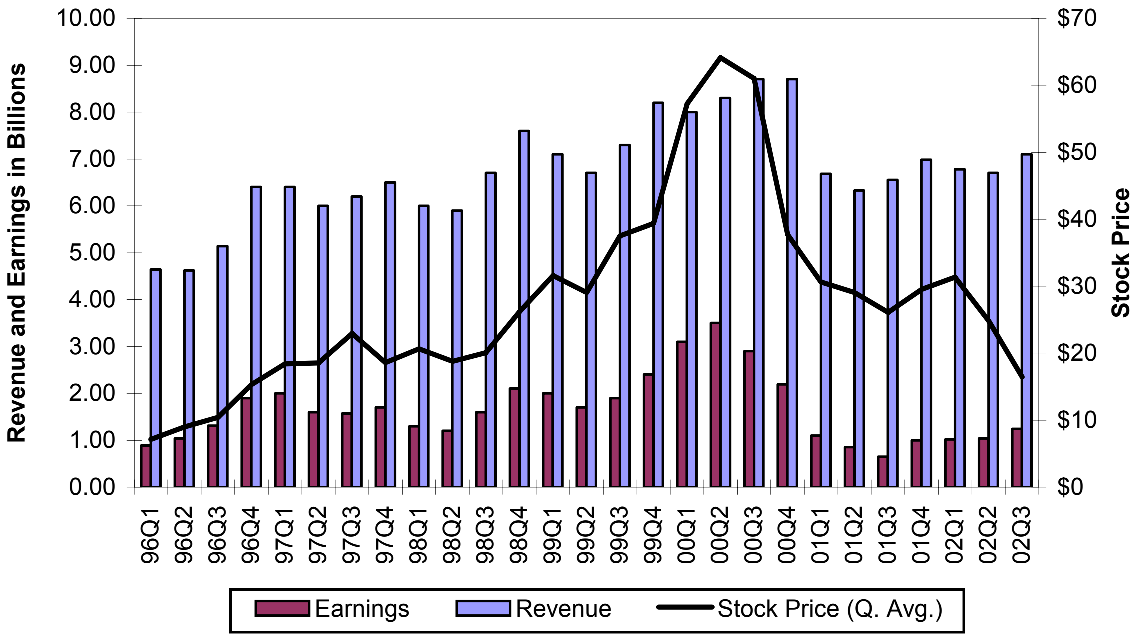
Otellini reiterated Intel's ultimate long-term objective: "Success comes when our communications group is indistinguishable from our PC group."

Exhibit 1 Intel's Financial Results (employees in thousands; all others in $ millions)

Year	Net Revenues	Cost of Sales	Employees	R&D	Net Income	Capital Additions	Total Assets	Market Capitalization
1974	135	68	3.1	11	20	13	75	–
1975	137	67	4.6	15	16	11	103	–
1976	226	117	7.3	21	25	32	157	–
1977	283	144	8.1	28	32	45	221	–
1978	399	196	10.9	41	44	104	357	663
1979	661	313	14.3	67	78	97	500	1,449
1980	855	399	15.9	96	97	156	767	1,763
1981	789	458	16.8	117	27	157	872	1,012
1982	900	542	19.4	131	30	138	1,056	1,755
1983	1,122	624	21.5	142	116	145	1,680	4,592
1984	1,629	883	25.4	180	198	388	2,029	3,192
1985	1,365	943	21.3	195	2	236	2,153	3,364
1986	1,265	861	18.2	228	-173	155	1,977	2,478
1987	1,907	1,044	19.2	260	248	302	2,499	4,536
1988	2,875	1,506	20.8	318	453	477	3,550	4,344
1989	3,127	1,721	21.7	365	391	422	3,994	6,290
1990	3,921	1,930	23.9	517	650	680	5,376	7,400
1991	4,779	2,316	24.5	618	819	948	6,292	9,996
1992	5,844	2,557	25.8	780	1,067	1,228	8,089	18,392
1993	8,782	3,252	29.5	970	2,295	1,933	11,344	26,334
1994	11,521	5,576	32.6	1,111	2,288	2,441	13,816	26,432
1995	16,202	7,811	41.6	1,296	3,566	3,550	17,504	48,439
1996	20,847	9,164	48.5	1,808	5,157	3,024	23,735	109,193
1997	25,070	9,945	63.7	2,347	6,945	4,501	28,880	114,718
1998	26,273	12,088	64.5	2,509	6,068	4,032	31,471	197,644
1999	29,389	11,836	70.2	3,111	7,314	3,403	43,849	275,006
2000	33,726	12,650	86.1	3,897	10,535	6,674	47,945	371,213
2001	26,539	13,487	83.4	3,796	3,661	7,309	44,395	218,824

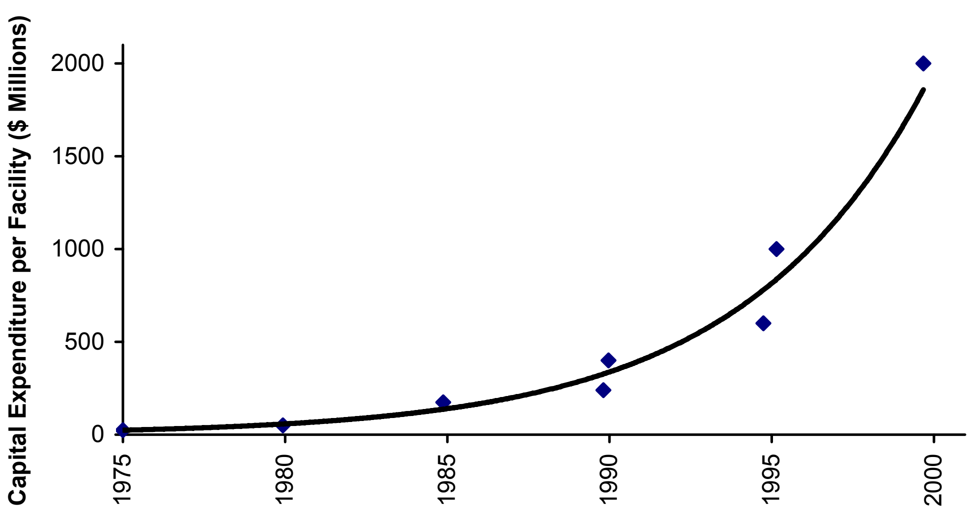
Source: Compiled by casewriters from company and analysts' reports.

Exhibit 2 Intel's Financial Results and Stock Price, Q1 1996 to Q3 2002



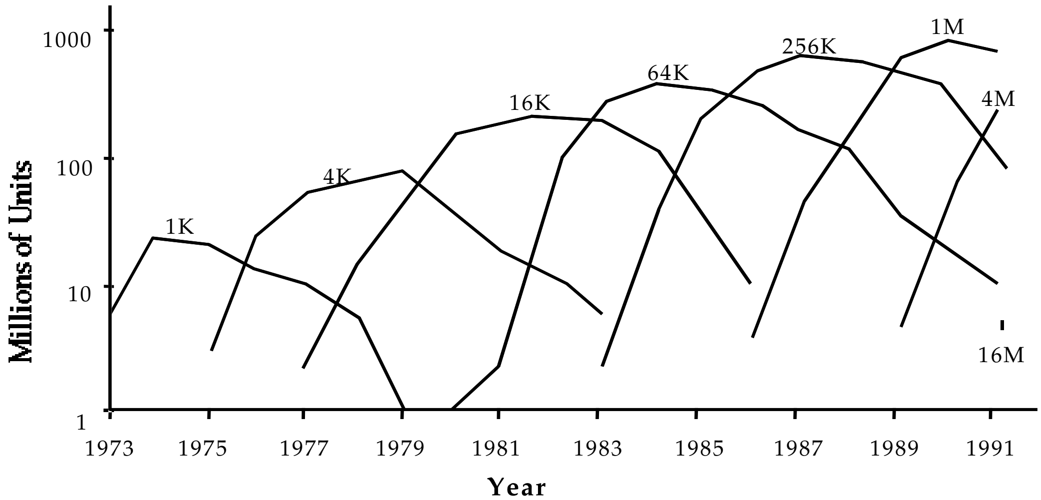
Sources: Compiled by casewriters from company and analysts' reports. Stock price computed by averaging monthly adjusted close prices.

Exhibit 3 Capital Cost per Semiconductor Manufacturing Facility



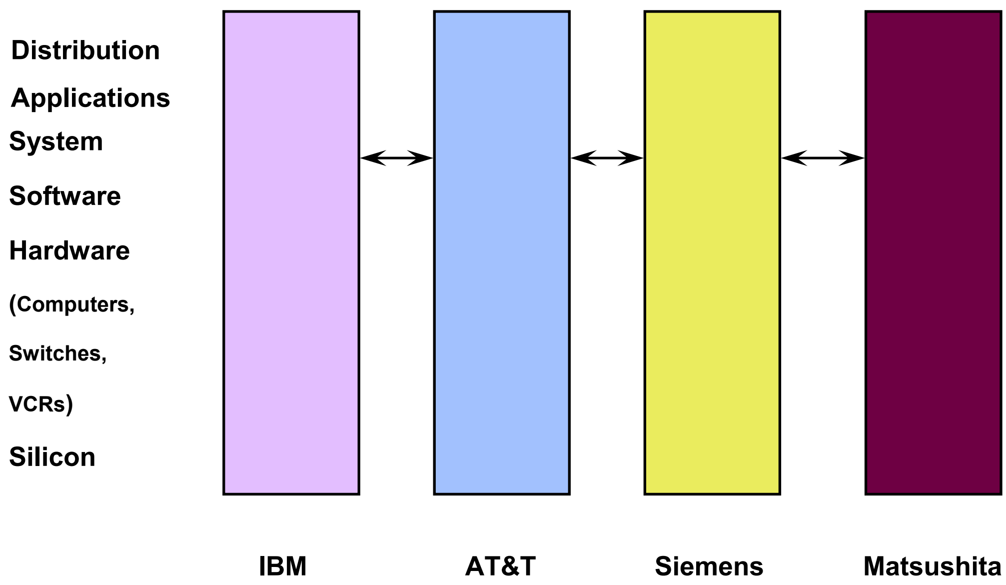
Source: Casewriters' updates of data from Jonathan West, "Institutional Diversity and Modes of Organization for Advanced Technology Development: Evidence from the Semiconductor Industry," DBA Thesis, Harvard Business School, 1996.

Exhibit 4 Volume Trends in DRAMs



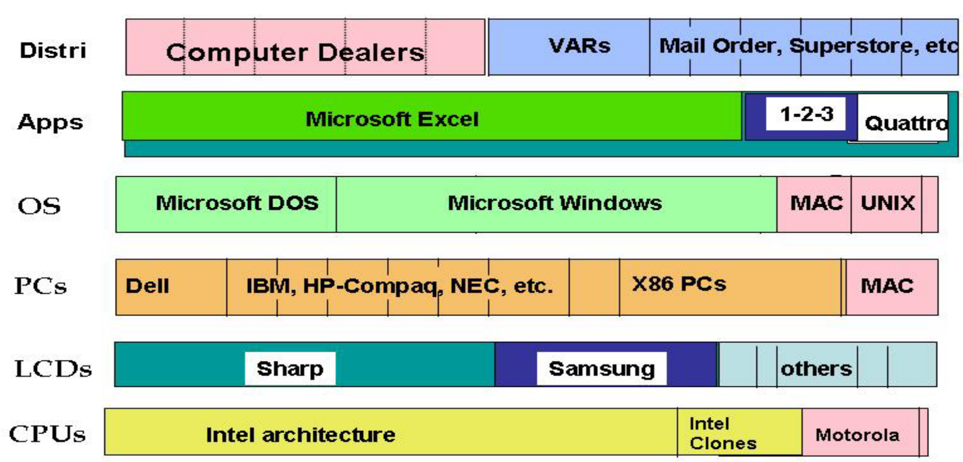
Source: Jonathan West, "Institutional Diversity and Modes of Organization for Advanced Technology Development: Evidence from the Semiconductor Industry," DBA Thesis, Harvard Business School, 1996.

Exhibit 5a Vertically Integrated Firms Competing Across All Segments



Source: Adapted from Intel documents and *The Economist* data.

Exhibit 5b



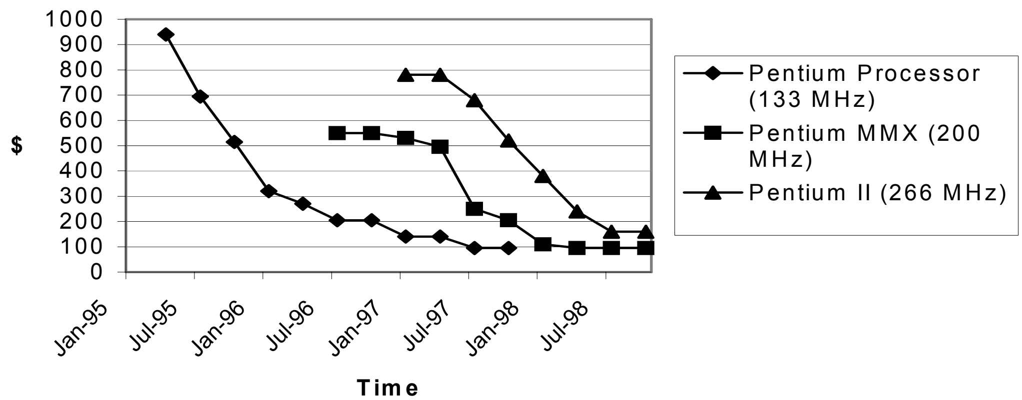
Source: Adapted from Intel documents, the Economist, Dept. of Defense, Flat Panel Display Task Force, 1994, not to scale.

Exhibit 6 Comparative Intellectual Property Considerations

	DRAMs	Microprocessors	EPROMs
Patent Protection Law	✓	✓	
Trade Secrets	✓	✓	✓
Copyrights		✓	
Trademarks		✓	
Chip Protection Act		✓	

Source: Company.

Exhibit 7 Intel Pricing: 1,000-Piece List Price



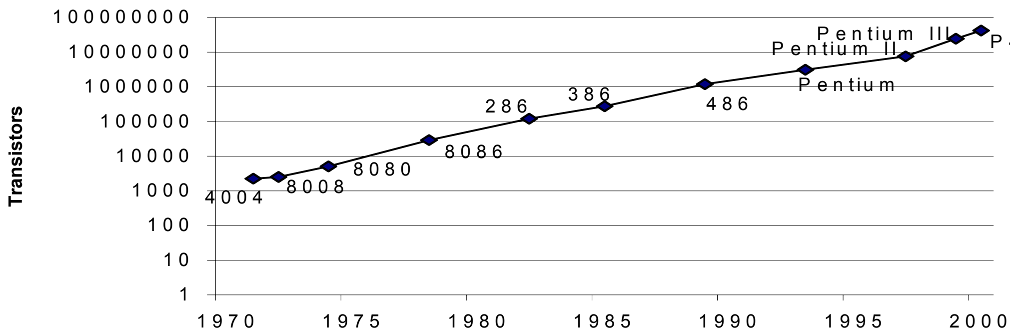
Source: Burgelman, Carter, and Bamford, "Intel Corporation: The Evolution of an Adaptive Organization," Stanford Business School Case #SM-95, 1999.

Exhibit 8 PC and Microprocessor Market Forecast

	1998	1999	2000	2001	2002	2003	99-03 CAGR
Worldwide PC Value of Shipments ($M)	170,152	182,966	194,737	208,465	222,726	239,009	6.9
Worldwide PC Microprocessor Revenue ($M)	19,457	23,104	25,550	26,307	25,899	24,470	1.6
Worldwide CPU Avg. silicon content $ value	211.03	206.01	196.02	178.38	153.98	127.37	–11.3

Source: Worldwide PC Forecast, Update, 1998–2003; Worldwide PC Semiconductor Market Forecast, International Data Corporation.

Exhibit 9 Moore's Law: The Number of Transistors on a Computer Chip Doubles Every 18 Months



Source: Intel Corporation.

Exhibit 10a Intel Customers

PCs	Servers	Communications	Wireless/Handhelds	Flash
Dell	Compaq	Cisco	Compaq IPAQ	Nokia
Compaq	Dell	Nortel	HP Jornada	Motorola
IBM	IBM	Lucent	Symbol Technology	Sony-Ericsson
HP	HP	Juniper	Casio	Lucent
Fujitsu Siemens	Fujitsu Siemens	Ciena	NEC	Mitsubishi
NEC	NEC	TranSwitch	Toshiba	NEC
Gateway	Fujitsu		Sony	Cisco
Toshiba	Hitachi		RIMM	Samsung
	Toshiba		Sharp	Siemens
	Gateway			Sony
	NCR			

Source: Pacific Crest analyst report, May 29, 2002, and Intel Corporation data.

Exhibit 10b Intel Competitors

PCs	Servers	Communications	Wireless/ Handhelds	Flash	Chipsets	ARM
AMD	Sun Micro	AMCC (MMC)	NEC	AMD	Broadcom	MOT
Transmeta	IBM	Agere	Broadcom	Fujitsu	Via Tech.	Samsung
Via Technologies	AMD	Motorola (C Port)	Toshiba	Sharp	SiS	Infineon
		Conexant	LSI Logic	Toshiba	Acer	IVM
		Vitesse	TI	ST Micro	nVidia	ST Micro
		EZChip	Philips	Mitsubishi	ATI Tech.	TI
		IBM	QED	Atmel		Toshiba
		Broadcom	IDT	SST		LSI Logic
			AMD	Samsung		Conexant

Source: Pacific Crest analyst report, May 29, 2002, and Intel Corporation data.

Glossary

Architecture A design. Architecture can refer to either hardware or software or to a combination of the two. The architecture of a system always defines its broad outlines and may define precise mechanisms as well. An *open architecture* allows the system to be connected easily to devices and programs made by other manufacturers. Open architectures conform to approved standards. A system with a *closed architecture* has proprietary design.

8, 16, 32, 64-bit architectures Refers to the number of binary digits, or bits of information, a microprocessor can retrieve from memory at one time.

Chip (or microchip) A unit of packaged computer circuitry manufactured from silicon at a very small scale. Chips are made for program *logic* (microprocessor chips) and for computer *memory* (RAM chips, for example).

Chipset A group of chips designed to work as a unit in performing one or more related functions. An example of a chip is the Intel 430HX PCIset for the Pentium.

Design win Refers to a chip manufacturer's successful procurement of a contract to furnish OEMs with its chipset. This usually occurs early in the design process of the OEMs' product and involves a very close working relationship where the chip manufacturer provides a range of services that facilitates the implementation of its chipset.[55]

Dynamic random access memory (DRAM) A type of semiconductor that provides random access memory (RAM) for the microprocessor. It is called "dynamic" because the information it carries has to be continuously refreshed from permanent storage.

EPROM memory A special type of memory that retains its contents until it is exposed to ultraviolet light. Ultraviolet light clears the contents, making it possible to reprogram the memory.[56]

Flash memory Small memory device that can hold large amounts of data. It is mainly used in personal digital assistants (PDAs), wireless phones, and laptop computers because it holds its data when the device is turned off.[57]

Magnetic core memory A form of storage in which rings of magnetic metal are woven together with interlocking strands of copper to form large rectangular arrays. Core memory was rendered obsolete by semiconductor memory.[58]

Microprocessor A semiconductor that acts as a computer's central processing unit (CPU). It performs logical functions based on programmed instructions from the computer's memory.

Microprocessor generation Refers to microprocessor speed for successive microprocessors. For example, fifth generation was between 100 and 200 MHz, sixth generation between 200 and 400 MHz, seventh generation between 400 and 800 MHz, and eighth generation between 800 and 1,600 MHz.

Moore's Law The number of transistors on a computer chip, and hence the processing power, doubles every 18 months. A consequence of Moore's Law is that the costs of computing fall by half every 18 months. (See **Exhibit 10**.)

Nonproprietary A technology process or product that is not protected by trademark, patent, or copyright. Nonproprietary products are in the public domain, and anyone can produce or distribute them.[59]

Endnotes

[1] See glossary for definitions of technical terms.

[2] Tim Jackson, *Inside Intel. Andy Grove and the Rise of the World's Most Powerful Chip Company* (New York: Penguin Group, 1997).

[3] Jackson, *Inside Intel*, p. 97.

[4] Daniel I. Okimoto, Takuo Sugano, and Franklin B. Weinstein, *Competitive Edge: The Semiconductor Industry in the U.S. and Japan* (Stanford, CA: Stanford University Press, 1984).

[5] Clyde V. Prestowitz, Jr., *Trading Places: How We Allowed Japan to Take the Lead* (New York: Basic Books, 1988), p. 46.

[6] Robert A. Burgelman & Clayton Christenson, "Intel Corporation's Internal Ecology of Strategy Making," Stanford Business School Case #SM95, 2002.

[7] Okimoto et al., *Competitive Edge*, p. 41.

[8] "Intel Corporation: 1968–1997," HBS Case No. 702-420 (Boston: Harvard Business School Publishing, 2002).

[9] Andrew S. Grove, *Only the Paranoid Survive* (New York: Doubleday, 1996), p. 89.

[10] "Brief History of Microprocessors," www-scm.tees.ac.uk/users/a.clements/History/History.htm, accessed September 25, 2002.

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