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Intel Corporation: 1968-1997

By January 1997, Intel, a Silicon Valley start-up, had attained a stock market valuation of $113 billion that ranked it among the top five American companies. Much of Intel's success had been due to microprocessors, a product it invented in 1971 and in which it continued to set the pace. Despite the company's illustrious history and enviable success, its Chairman and CEO, Andy Grove, worried about the challenges ahead:

> Business success contains the seeds of its own destruction. The more successful you are, the more people want a chunk of your business and then another chunk and then another until there is nothing left. I believe that the prime responsibility of a manager is to guard constantly against other people's attacks.[1]

This case begins by describing Intel's origins as a semiconductor company before turning to its evolution into the leading manufacturer of microprocessors.

Intel: The Early Years

Intel was founded in 1968 by Robert Noyce (one of the co-inventors of the integrated circuit) and Gordon Moore, both of whom had been senior executives at Fairchild Semiconductors. They, in turn, recruited Andy Grove, who was then Assistant Director of Research at Fairchild. From the beginning, this trio was the driving force behind Intel. The company's initial strategy was to develop semiconductor memory chips for mainframe computers and minicomputers.

Andy Grove recalled that after receiving a Ph. D. in chemistry from the University of California at Berkeley, he interviewed for jobs at Bell Laboratories as well as Fairchild. For him, "the choice was very easy: Bell Labs was *the* place to work back then. So I picked Fairchild."[2] Grove's youthful bravado was tempered by some concerns when he moved to Intel:

> When I came to Intel, I was scared to death. I left a very secure job where I knew what I was doing and started running R&D for a brand new venture in untried territory. It was

[1] Andrew S. Grove, *Only the Paranoid Survive* (New York: Currency/ Doubleday, 1996), p. 3.

[2] Brent Schlender, "Why Andy Grove Can't Stop," *Fortune* (July 10, 1995), p. 92.

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> terrifying. I literally had nightmares.[3] [Also,] I was supposed to be director of engineering, but there were so few of us that they made me director of operations. My first assignment was to get a post office box so we could get literature describing the equipment we couldn't afford to buy.[4]

Then as now, Silicon Valley was a welcome place only for those willing to take risks and tackle difficult problems. According to Noyce,

> I used to characterize our business…as working on the edge of disaster. We are absolutely trying to do those things which nobody else could do from a technical point of view. And our industry's unique in that because it is very, very complex in terms of technology that goes into it. It's very, very easy to make a mistake. We're working where a speck of dust ruins everything.[5]

Intel in the DRAM Business

Intel's first two products were introduced in 1969: the 3101 (a 64-bit bipolar static random access memory, or SRAM) and the 1101 (a 256-bit MOS—metal oxide semiconductor—SRAM).[6] Despite being technically advanced, neither product was a commercial success. Then, in 1971, Intel introduced the 1103, a 1-kilobit DRAM (dynamic random access memory) chip.[7] By 1972, the 1103 was the world's best selling semiconductor product, accounting for over 90% of the company's sales revenues.

From the beginning, Intel's strategy was to push the envelope of product design and to be first to market with the newest devices. This strategy obviously required strong capabilities in product design. Since semiconductor manufacturing processes were enormously complex and influenced the characteristics of the product, Intel had to stay on the leading edge of process technology as well. With each new generation of product technology, the company was forced to invest heavily in new manufacturing equipment capable of producing ever more complex devices (see **Exhibit 1**). Moreover, production yields—a key driver of semiconductor manufacturing costs—would fall dramatically with the introduction of new processes. Yields would only rise as the plant gained experience with the new process, identified and resolved trouble-spots, and exploited opportunities for process optimization and improvement. However, DRAM prices for any given generation device would fall dramatically once competitive capacity came on line (see **Exhibit 2** and **Exhibit 3**). Because basic DRAM technology was widely diffused, patents were generally not considered effective at blocking entry.

Until around 1979, Intel's strategy appeared to work well. Across four generations of DRAMS (1K, 2K, 4K, and 16K), Intel succeeded in introducing devices and process technologies that were ahead of the competition and in commanding significant price premiums. But this strategy of

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3 *Intel: 25th Anniversary* (order no. 241730), 1993, p. 2.

4 Brent Schlender, "Why Andy Grove Can't Stop," p. 92.

5 Quoted by Lynn M. Salerno, "Creativity by the Numbers: An Interview with Robert N. Noyce," *Harvard Business Review* (May/ June 1980), pp. 129-130.

6 These and other technical terms are explained in the glossary on page 24.

7 The memory capacity of a semiconductor is determined by the number of "bits" that can be stored on a chip. A "bit" is simply a piece of binary code (either a 0 or a 1). A 1-K DRAM, for example, can store approximately 1000 bits. Successive generations of DRAMs increased the storage density to 2,000 (2K), 4K, 16K, 256K, and so on. In 1997, state of the art memory devices had the capacity to store 256 million bits.

leadership at product development was tested as product life cycles for DRAMs began to shrink and Japanese competitors began to introduce new products more rapidly. For example, in 1979, Intel introduced a 16K DRAM that incorporated a single power supply design, a feature that enabled the company to charge a price approximately double that of competitive devices. Fujitsu responded to this product by introducing a 64K DRAM with a conventional design. Although Fujitsu's device lacked the single power feature of the Intel product, it had a higher memory capacity and thus quickly captured a significant share of the DRAM market. Fujitsu's higher market share translated into higher cumulative production volumes, which in turn, gave the company a manufacturing cost advantage. This scenario was repeated again in 1982 when Intel introduced an improved version of the 64K DRAM, only to soon lose market share to Fujitsu and Hitachi who introduced their own 256K products. Japanese producers also beat U.S. competitors to market with 1 megabit DRAMs by more than a year and a half.

A key element of the Japanese strategy in DRAMs was to invest heavily in manufacturing. Between 1980 and 1984, Japanese firms invested 40% of their sales revenues in new plant and equipment, versus 22% for U.S. firms.[8] Japanese semiconductor manufacturers also had an important technological advantage in photolithography (the process whereby circuits are etched onto silicon wafers). Japanese DRAM producers, including Fujitsu, Hitachi and NEC, worked closely with equipment manufacturers, including Nikon, to design superior equipment that did not become available in the United States until later.[9] By the early 1980s, Japanese production yields for semiconductors were as high as 70% to 80%, versus 50% to 60% at best for U.S. firms.[10] More importantly, Japanese competitors in DRAMs were much faster at developing process technologies and ramping up production capacity (and improving yields) than their American counterparts. Intel found that during the mid-1980s, its new product introductions were being delayed by about 2 years because of problems developing and ramping-up production processes.[11] By the early 1990s, Japanese semiconductor companies had captured nearly half the world market for DRAMs (see **Exhibit 4** for additional market share data).

Intel and the Microprocessor

In 1970, a Japanese firm called Busicom contracted with Intel to make a set of chips for an electronic calculator. Intel scientist Ted Hoff responded with an innovative design that represented the first semiconductor "central processing unit," or CPU. The market for this product, the 4004, was not immediately apparent, but Intel decided to purchase the non-calculator rights to the 4004 from Busicom. Three years later Intel introduced an 8-bit microprocessor called the 8080. The early microprocessors were heralded as a great technological advance, but Intel executives apparently did not foresee their true commercial potential as the "brains" for a microcomputer. According to Gordon Moore,

> In the mid-1970s, someone came to me with an idea for what was basically the PC. The idea was that we could outfit an 8080 processor with a keyboard and a monitor and sell it in the home market. I asked, 'what's it good for?' And the only answer was that a housewife

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[8] George W. Cogan, "Intel Corporation (A): The DRAM Decision," Graduate School of Business, Stanford University case BP-256A, p. 13.

[9] Robert A. Burgelman, "Fading Memories: A Process Theory of Strategic Business Exit in Dynamic Environments," *Administrative Science Quarterly* 39 (1994), p. 34.

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

[11] Source: Gita Mathur under the supervision of Professor Robert H. Hayes, "Intel-PED (A)," Harvard Business School case no. 693-056.

could keep her recipes on it. I personally didn't see anything useful in it, so we never gave it another thought.[12]

Although Moore initially did not recognize the vast potential of the microprocessor, others did. In 1977, Steve Jobs and Steve Wozniak founded Apple Computer to produce the first desktop computers using a non-Intel microprocessor as the central processing unit. In that same year, Radio Shack and Commodore also entered the desktop computer market. By 1980 it was estimated that these three companies controlled two-thirds of the total market, led by Apple with a market share of 27%.[13]

The Battle to Set a Personal Computer Standard

Since none of the desktop computer companies were able to produce microprocessors, it was left mainly to Intel and Motorola to compete for this emerging market. Each company introduced second generation, 16-bit microprocessors: Intel's 8086, introduced in 1978, and Motorola's 68000, introduced a year later. Despite its first-to-market advantage, the 8086 initially languished. Apple Computer chose Motorola's chip as its standard. Years later, Andy Grove lamented the fact that "here we were just two miles away from Apple and we didn't take it seriously. It set us back in a big way."[14]

When IBM decided to enter the microcomputer market with its Personal Computer, or PC, in early 1980, its strategy was designed to gain a large market share as quickly as possible, in order to set a standard and create economies of scale in what was still a relatively fragmented market. IBM decided that the fastest way to grow the PC business was to adopt an open architecture, whereby the company's PCs would use software and components (including the microprocessor) that any company could buy from third-party vendors.

This decision led to a fierce battle between Intel and Motorola, with both companies knowing that none of the other microcomputer manufacturers were likely to have the market power to challenge IBM's standard. Thus, in 1980 Intel initiated "project CRUSH," a sales effort intended to secure 2,000 design wins that year, including the IBM contract. The campaign succeeded, recording 2,500 design wins, including a contract to supply IBM with the 8088 microprocessor, an 8-bit version of the 8086. The 8086 rode the coattails of IBM's highly successful PC division, which became a Fortune 500-sized operation in 1983. By 1985, the PC generated $5.5 billion in revenues for IBM, an increase of $5 billion in four years.[15]

Despite this monumental victory, Intel continued its aggressive marketing against Motorola. In fact, Motorola's 68000 standard managed to dominate the workstation market until the late 1980s, while also serving as the architecture for Apple's Macintosh computer. Thus, when Intel introduced its next-generation microprocessor, the 80286, in 1983, it launched "project CHECKMATE," another all-out effort to win contracts for its product. Dennis Carter, a manager involved in marketing the

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[12] *Intel: 25th Anniversary* (order no. 241730), 1993. p. 12.

[13] Alfred D. Chandler, Jr. "The Computer Industry-The First Half-Century," seminar paper, Nov. 15, 1996, p. 52.

[14] Quoted by Nick Hasell, "The Intelligence of Intel," *Management Today* (November 1992), pp. 76-78.

[15] Alfred D. Chandler, Jr., "The Computer Industry-The First Half-Century," p. 49.

80286, noted that "when we went into CHECKMATE, some market segments were three or four to one in favor of Motorola. By the time we finished, it had turned around the other way."[16]

Exit from DRAMs

In 1984, Intel scientists designed a 1 megabit DRAM. Since the industry standard at the time was a 256 kilobit DRAM, Intel's new chip had the potential to "leapfrog" the rest of the industry. The question was whether Intel was willing to risk the hundreds of millions of dollars necessary to produce the 1M DRAM in volume. Moreover, production of a device this complex would once again require significant advances in process technology, an area in which Japanese DRAM competitors seemed to have a commanding lead. The 1M DRAM would only be successful if Intel reached the market and achieved commercially viable manufacturing yields before Japanese competitors introduced their own 1M DRAMs. In 1984, Intel took the difficult decision of halting further development of its 1M DRAM.

Over the next two years, Intel continued to invest R&D in DRAMs. The firm had always regarded DRAMs as its main "technology driver," meaning it was the product area where new process techniques were applied first. The effectiveness of DRAMs as a technology driver was enhanced by the fact that the market demanded high volumes at low prices which enabled DRAM producers to develop economies of scale that would not have been possible with other devices (such as microprocessors) during that time. In 1985, DRAMs still accounted for as much as one-third of Intel's research and development expenditures,[17] although they generated only 5% of Intel's revenues.[18] Intel had also become a relatively small player in the DRAM market (see **Exhibit 5**).

While senior management remained committed to the DRAM business through 1986, mid-level Intel managers had begun to shift the company's production resources away from DRAMs well before it became official company strategy. As Andy Grove explained, "By mid '84, some middle level managers had made the decision to adopt a new process technology which inherently favored logic (microprocessor) rather than the memory advances, thereby limiting the decision space within which top management could operate."[19]

Grove emphasized the way in which the firm's exit from DRAMs was precipitated not by top management but by the day-to-day actions of middle managers. In his words,

> Over time, more and more of our production resources were directed to the emerging microprocessor business, not as a result of any specific strategic direction by senior management but as a result of daily decisions by middle managers: the production planners and the finance people who sat around the table at endless production allocation meetings. Bit by bit, they allocated more and more of our silicon wafer production capacities to those lines which were more profitable, like microprocessors, by taking production capacity away from the money-losing memory business. Simply by doing their daily work, these middle managers were adjusting Intel's strategic posture. By the time we made the decision to exit the memory business, only one out of eight silicon fabrication plants was producing memories. While

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[16]Quoted by George W. Cogan, "Intel Corporation (A): The DRAM Decision," Graduate School of Business, Stanford University, Case BP-256A (1990), p. 8.

[17] Robert A. Burgelman, "Intraorganization Ecology of Strategy Making and Organizational Adaptation: Theory and Field Research," *Organization Science* 2 (August 1991), p. 245.

[18] *Intel : 25th Anniversary*, order no. 241730 (1993), p. 21.

[19]Quoted by Robert A. Burgelman, "Intraorganization Ecology of Strategy Making," pp. 251-252.

> management was kept from responding by beliefs that were shaped by our earlier successes, our production planners and financial analysts dealt with allocations and numbers in an objective world. For us senior managers, it took the…sight of unrelenting red ink before we could summon up the gumption needed to execute a dramatic departure from our past.[20]

The independence shown by middle management ranks was consistent with Intel's entrepreneurial culture, which the company had struggled to retain despite its rapid growth. In 1980, Bob Noyce had explained that "strategic planning is embedded in the organization. It is one of the primary functions of line managers. They buy into the program; they carry it out. They're determining their own future, so I think the motivation for doing it well is high."[21] By 1986, the company's senior management officially approved middle managers' decisions to exit from the DRAM business and focus resources on microprocessors.

Intel as a Microprocessor Company

The 80386 Manufacturing Strategy

As the first truly mass-market computer, the PC offered many challenges to its producers. At the outset, IBM knew it would take many years before it could generate sufficient economies of scale in all components, so instead it chose to purchase many components from outside vendors. Nonetheless, it took a huge organizational commitment over several years to create an assembly and distribution network for the PC. Intel, for its part, knew that it did not have the capacity to fabricate microprocessors on the scale that was projected for the PC. Indeed, to meet demand for the 8086, Intel had to license as many as 12 other companies to produce the chips, leaving Intel with only 30% of the total revenues and profits from that product. Intel did better with the second-generation 80286, licensing only four second sources and retaining 75% of revenues and profits. For the third-generation 80386, only IBM was granted a license to make the chips, and these were used only in IBM's own computers.[22] Thus, for all PC makers except IBM, Intel was the sole source for the 386.

The decision not to license production of the 386 brought about a major transformation of Intel's organization. Within two years of its introduction, estimates were that 800,000 units had been delivered. By contrast, the 8086 had shipped 50,000 units in its first two years.[23] As Grove recalled,

> We had to commit to supplying the entire needs of the industry. That motivated us to get our manufacturing performance up to snuff. We developed multiple internal sources, so several factories and several processes were making the chips simultaneously. We made major commitments to production ramps, and we didn't hedge.[24]

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[20] Andrew S. Grove, *Only the Paranoid Survive* (New York: Currency/ Doubleday, 1996), pp. 96-97.

[21] Quoted Lynn M. Salerno, "Creativity by the Numbers: An Interview with Robert N. Noyce," *Harvard Business Review* (May/ June 1980), p. 123.

[22] Professor David Yoffie, Ralinda Laurie, and Ben Huston, *Intel Corporation 1988*, Harvard Business School case #389-063 (1989), p.99.

[23] George W. Cogan, "Intel Corporation (C): Strategy for the 1990s," Graduate School of Business, Stanford University, Case BP-256C, p. 6.

[24] Andrew S. Grove, *Only the Paranoid Survive*, pp. 69-71.

One long-range impact of the 386 decision for Intel was that it became more dependent on the price premium it could charge for a new generation of microprocessors. It was estimated that the 386 had cost Intel $200 million to develop (not including capital expenditures for manufacturing capacity—a figure that could have approached another $800 million).[25] In Grove's words, "Our resolve hardened by tough business conditions, we decided to demand tangible compensation for our technology. Our competitors were reluctant to pay for technology that we used to give away practically for free."[26]

At the same time that Intel was deciding whether to license 386 production to third-parties, IBM made a decision that would have an even greater impact on the PC industry. After spending a half-decade watching outside component manufacturers capture a significant share of the value from PCs, IBM decided not to sell any 386-based computers until it could develop a new architecture that would use more of IBM's own proprietary components. For Intel, of course, this meant that their biggest customer would not commit to buying its newest product.

Fortunately for Intel, however, a young firm named Compaq rushed in to fill the gap. Compaq had been formed in 1983 to market portable PCs and had almost no experience in selling desktop systems, but in mid-1986 it leaped into the market with its Deskpro 386. It was an all-out gamble by a small firm with seemingly nothing to lose and everything to gain. At first, Compaq could not even be sure that PC buyers would want 386s instead of the cheaper 286 computers still being sold by IBM and many others. Michael Swavely, Compaq's marketing vice-president, offered the assessment that "the 386 architecture will become the mainstream business PC certainly by the '89 timeframe."[27] In hindsight, Swavely's prediction was far too modest. The Deskpro 386 became an immediate hit with consumers. By 1989, the *fourth* generation 80486 was already generating heavy orders from PC buyers.

Another potential stumbling block to the 386 was software. The 386 was a 32-bit microprocessor offering several important technological advances, including virtual memory and multitasking, but these features were not yet supported by existing versions of MS-DOS (the Microsoft Disk Operating System). Indeed, at the time the 386 was introduced, Microsoft was still working on DOS 4.0, which was intended to optimize the capabilities of the *286*. Microsoft claimed that it would release a DOS 5.0 for the 386, but this project was nowhere near completion in 1985.

The delay in getting an operating system for the 386 was another serious risk for Intel. Dave Vineer, who led the design team for the 386SL, said in 1991 that "we introduced the 386 in October 1985, and by November, we were all very frustrated that significant 32-bit applications hadn't yet surfaced and that Microsoft hadn't done a 32-bit DOS." However, Vineer understood that "clearly, there needs to be a critical mass of installed hardware, and there has to be a clear…market for the 32-bit software in order for it to be produced." He then acknowledged that the market for 32-bit software had only begun to develop in a significant way since the 486 was introduced in 1989.[28]

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25 Professor David Yoffie, Ralinda Laurie, and Ben Huston, *Intel Corporation 1988*, Harvard Business School case no. 389-063, p.98.

26 Andrew S. Grove, *Only the Paranoid Survive*, (New York: Currency/ Doubleday, 1996), p. 70.

27 Quoted by Ira Sager, "386 Tempts More PC Firms to Beat IBM in Market Race," *Electronic News* (September 29, 1986), p. 1.

28 Quoted by Owen Linderholm, Rich Malloy, Andrew Reinhardt and Kenneth M. Sheldon, "A Talk with Intel," *Byte* 16 (April 1991), p. 131.

The Computer Industry Transformed

The remarkable ascendancy of Compaq, Intel and Microsoft in the late 1980s was exactly the opposite of the result IBM had hoped to achieve by redefining the PC standard (see **Exhibit 6**). In the long run, the 386 dealt a severe blow to IBM's previous dominance of the desktop market. Grove's later assessment of IBM's strategy was harsh. In 1993, Andy Grove claimed that

> 1986 is when IBM began to lose it. For reasons of their own, they were reluctant to get involved with our 386 microprocessor. That's when Compaq got into the act. Then in 1990, Microsoft split with IBM and introduced Windows 3.0.

For his part, William Gates (founder and CEO of Microsoft) concurred:

> Compaq's decision to come out with a 386 system before IBM is the big transition. Both our companies really encouraged Compaq to not just be the leader in portables, which is what they were at that point, but to be the performance leader too. After that, there was a bit of a vacuum in PC leadership and both of our organizations recognized the need and opportunity to step in and fill it. But one key thing to know about the chronology of our relationship is that there's been more time spent on Intel/Microsoft collaboration in the last couple of years than in all the preceding decade put together.[29]

The rise of the 386 marked a growing interdependence among firms in the computer industry (see **Exhibits 7** and **8**). Grove argued that in the 1980s, the computer industry was transformed from a "vertical" alignment, based on the exclusive use of proprietary technologies, to a "horizontal" alignment with open standards. As he put it, "a vertical computer company had to produce computer platforms *and* operating systems *and* software. A horizontal computer company, however, supplies just one product. By virtue of the functional specialization that prevails, horizontal industries tend to be more cost-effective than their vertical equivalents."[30]

Sustaining Dominance in the Microprocessor Industry

The decision not to license the 386 to any manufacturer other than IBM positioned Intel as the leading player in its "horizontal" niche within the computer industry. But in sustaining that lead, it faced challenges from numerous players. This section describes how Intel managed its relationships with three classes of players: competitors, buyers and suppliers.

Competitors

The RISC Threat

In 1989, as Intel launched its fourth generation 80486 microprocessor, it faced a potential competitive threat from an alternative microprocessor architecture, RISC (Reduced Instruction Set Computing). RISC was generally regarded as having speed and cost advantages over the CISC (Complex Instruction Set Computing) architecture of Intel's X86 line. RISC processors had come to dominate the workstation market, which used the UNIX operating system. The threat was that as the price/performance ratio of RISC processors improved, they might invade the PC's domain in office

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[29] Quoted by Brent Schlender, "A Conversation with the Lords of Wintel," *Fortune*, July 8, 1996, pp. 26-33.

[30] Andrew S. Grove, *Only the Paranoid Survive*, (New York: Currency/ Doubleday, 1996), p. 52.

computing. Analysts were predicting that RISC machines might grab as much as 40% of the office market within five years.[31] T.J. Rodgers, CEO of Cypress Semiconductor (a manufacturer of Sun's SPARC chip), argued that "there's enough ambiguity that it is really a marketing pitch that will win or lose this war."[32]

For Motorola, however, there was no ambiguity. "We're in a big-time war, going for gigantic stakes. We're talking about the next generation of computers and who's going to win or not," said Murray Goldman, Motorola's microprocessor group general manager.[33] To boost its 88000 RISC processor, Motorola ran 13 full page ads in the *Wall Street Journal*. James Norling, executive vice president and head of Motorola Inc.'s Semiconductor Products Sector, commented that the ads were intended to create "the sense that we're committed. You don't advertise something in full-page *Wall Street Journal* ads and then blow it off."[34]

For Motorola, RISC versus CISC was a serious issue because its 68000-series CISC chips had been largely displaced in the workstation market by RISC microprocessors like the Sun SPARC and Silicon Graphics' Mips. For Intel the immediate threat was less serious because RISC chips were not yet considered a threat to Intel's desktop market. However, Intel did have a powerful RISC microprocessor of its own, the i860. The question was whether Intel should push the i860 (a RISC architecture) as a possible substitute for its X86 line (a CISC architecture).

For Intel to have a RISC alternative was fortuitous. The company had never changed its official policy of developing only products that were fully compatible with the X86 software base. Thus, as Grove explained,

> To get under the management radar screen that guarded our compatibility dogma, the engineers and technical managers who believed RISC would be a better approach camouflaged their efforts and advocated developing their chip as an auxiliary one that would work with the 486. All along, of course, they were hoping that the power of their technology would propel their chip into a far more central role. We now had two very powerful chips that we were introducing at just about the same time: the 486, largely based on CISC technology and compatible with all the PC software, and the i860, based on RISC technology, which was very fast but compatible with nothing. We didn't know what to do. So we introduced both, figuring we'd let the marketplace decide.[35]

At first, Intel made considerable efforts to sell the i860. Indeed, Forest Baskett, vice president for R&D at Silicon Graphics, claimed that Intel was pushing its "IBM connection," hinting that IBM was going to adopt the i860 as its standard. In Baskett's words, "what they're trying to do is make people believe that the i860 in IBM-land is going to eventually supplant or be an equal to the 386 and 486."[36]

Compaq officials were apparently worried that the 860 might be developed as a new proprietary standard for desktop computing, which might undermine its position as a leading PC distributor. To reinforce the X86 standard, Compaq invested in a start-up company called NexGen, which had the

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[31] Quoted by Michael R. Leibowitz, "The Microprocessor Marketing Wars," Electronic Business (July 10, 1989), p. 28.

[32] Quoted by Michael R. Leibowitz, "The Microprocessor Marketing Wars," p. 28.

[33] Quoted by Michael R. Leibowitz, "The Microprocessor Marketing Wars," p. 28.

[34] Quoted by Michael R. Leibowitz, "The Microprocessor Marketing Wars," p. 28.

[35] Andrew S. Grove, *Only the Paranoid Survive*, (New York: Currency/ Doubleday, 1996), pp. 104-106.

[36] Quoted by Michael R. Leibowitz, "The Microprocessor marketing Wars," *Electronic Business* (July 10, 1989), p. 28.

capability to design microprocessors that could act as substitutes for Intel's X86. Compaq's stake was reported to be 10%.[37]

In fact, Compaq put direct pressure on Intel to recommit itself to the X86 standard, as Grove later revealed, "On the one hand, the CEO of Compaq…leaned on us—on me, in particular—and encouraged us to put all our efforts into improving the performance of our older CISC line of microprocessors."[38]

The decision between RISC and CISC was further complicated by the fact that "the key technology manager at Microsoft…was encouraging us to move toward an '860 PC.'" For Intel, the issue was not resolved until Grove went to Chicago for the unveiling of the 486 in 1989. As he recalled,

> I remember sitting at the product introduction in Chicago with a virtual Who's Who of the computer manufacturing world, all of whom showed up to announce their readiness to build 486-based computers, and thinking, "RISC or no RISC, how could we possibly not put all our efforts into supporting this momentum?" After this event, the debates were over and we refocused our efforts on the 486 and its successors.[39]

The "momentum" Grove referred to was known to emanate from the unwillingness of users to switch to a new architecture that would not offer full software compatibility with their old architecture (see **Exhibit 9**). Vin Dham, vice president and general manager of the Intel group responsible for developing the Pentium (the next generation after the 486), said that Intel's goal was to

> . . . minimize the performance difference between our architecture and the best RISC guys. If we're close, our customers won't switch. It isn't worth their while. Switching takes a lot of effort…[in the early 1990s] we did extensive investigations and asked our customers, "What would it take to get you to switch?" They said it would take more than a 2X difference in performance.[40]

The threat of RISC led to a stepping up of Intel's R&D for new generations of the X86. It decided to develop two generations of its X86 line simultaneously (the Pentium and Pentium Pro) and to commit to a massive expansion in fabrication capacity for these products.

The Threat from Clones

Semiconductor companies had historically not been very vigilant in enforcing intellectual property rights through patent infringement suits and related legal strategies. The reason for this stance was that technology moved so rapidly that patents quickly became economically obsolete. In addition, since most companies drew from common underlying technology bases, it was not always clear who might be infringing upon whom.

In the late 1980s, Intel took a different approach to competitors that it regarded as cloning its products. Bob Reed, Intel CFO, said that in the early 1990s "Intel has looked around for an edge against competitors. When we look back ten years from now we may see that intellectual property

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37 Jaikumar Vijayan, "AMD to Bolster Intel Defenses," *Computerworld* (October 30, 1995) p. 32.

38 Andrew S. Grove, *Only the Paranoid Survive*, (New York: Currency/ Doubleday, 1996), pp. 105-106.

39 Andrew S. Grove, *Only the Paranoid Survive*, p. 106.

40 Quoted in Dan Steere, "Intel Corporation (D): Microprocessors at the Crossroads," Graduate School of Business, Stanford University Case BP-256D (1994), p. 5.

protection saved the U.S. semiconductor market. The protection will essentially lead to a segmentation of the semiconductor industry into maybe ten segments, all with leaders."[41] However, Intel's vigorous protection of its intellectual property was not entirely successful at blocking entry into microprocessors. Intel's litigation against AMD was an example. In 1976, the two companies signed a contract that gave AMD perpetual rights to all of Intel's microcode for its "microcomputers," then and in the future. Intel had received $325,000 for the deal. However, in 1987 Intel unilaterally abrogated the agreement arguing that a "microcomputer" and a "microprocessor" were different things, so AMD had no right to Intel's microprocessor code. The result was an eight-year legal battle costing hundreds of millions of dollars. Finally, in 1995 a settlement was reached in which AMD got full rights to Intel's microcode for the 386 and 486, but no right to the Pentium or any future Intel designs. Intel got $40 million in damages—considerably less than its legal bills for 1994 and 1995 alone.[42]

By the early 1990s, Intel faced credible threats from a number of rivals, including AMD, Texas Instruments and Cyrix who could produce microprocessors compatible with Microsoft's MS-DOS operating system. AMD had long made heavy investments in manufacturing facilities and in process engineering capabilities.[43] Its weakness was in chip design, but this was remedied in October 1995, when AMD acquired NexGen Inc., which had a viable sixth generation design, the Nx686. Jerry Sanders, chairman and chief executive officer of AMD claimed that "we intend to have 30% of the Windows-compatible market by 1998."[44] According to Rob Herb, a vice president of AMD's computational products group, with the K-6 chip, AMD is now "not just playing in the entry-level space but across the broad range of product offerings," while continuing to price its chips roughly 25% below Intel.[45] John Greenagel, an AMD spokesman added, "We intend to dog Intel forever."[46]

To counter-attack these competitors, Intel's strategy for its fifth (Pentium) and sixth (Pentium Pro) generation microprocessors was to achieve an overwhelming advantage in performance over competitive offerings. Albert Yu, who along with Paul Otellini, was responsible for Intel's microprocessor development efforts, explained that

> Volume is key to everything. A leading edge design will take 50 to 100 top engineers two or three years to develop. Total development costs will probably range from $50 to $100 million. In addition to that, the processor must make use of the latest manufacturing technology to be cost effective. A leading edge fab [semiconductor plant] can require $700 to $800 million in capital investment. You have to sell a lot of processors to recoup those costs (see **Exhibit 10**).[47]

Cost recovery was further complicated by the fact that prices for each generation of microprocessors would, as in the case of DRAMs, fall dramatically after introduction (see **Exhibit 11**).

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41 Quoted by George W. Cogan, "Intel Corporation (C): Strategy for the 1990s," Graduate School of Business, Stanford University, Case BP-256C (1991), p. 7.

42 Jaikumar Vijayan, "AMD to Bolster Intel Defenses," *Computerworld* (October 30, 1995), p. 32.

43 Jaikumar Vijayan, "AMD to Bolster Intel Defenses," p. 32.

44 Quoted by Brooke Crothers, "AMD, NexGen to Merge, Jointly Develop K6 Chip," *Infoworld* (October 30, 1995), p. 35.

45 Ken Yamada, "AMD Seeks to Compete with Intel on Pentium Pro Level," *Computer Reseller News* (September 2, 1996),p. 6.

46 Anonymous, "The Microprocessor Market: Chipping Away," *Economist*, (November 14, 1992), pp. 82-84.

47 Dan Steere, "Intel Corporation (D): Microprocessors at the Crossroads," Graduate School of Business, Stanford University, Case BP-256D, p. 5.

Customers

Depending on the exact configuration of the system and the time in the product life cycle, the microprocessor could account for 20% to 40% of the total manufacturing costs of a personal computer. In addition, despite the entry of AMD and others into the business, Intel was the overwhelmingly dominant supplier of microprocessors, with a market share of approximately 90%.

These interdependencies led to complex and sometimes tense relationships between Intel and its customers, as highlighted by the following three decisions and practices: one was the company's decision to begin the "Intel Inside" advertising program. A second was its growing involvement in sub-system and full-system design and manufacturing (rather than just microprocessors). The third major area of tension concerned how it allocated supplies of newly launched chips in the face of tight capacity constraints. Each of these is examined below.

"Intel Inside"

In 1990, Intel introduced the "Intel Inside" advertising campaign in an effort to create brand recognition among PC users. For the most part, Intel had always regarded its "customers" as the original equipment manufacturers (OEMs) who marketed finished computer systems. "Intel Inside" was designed to complement the marketing efforts of OEMs. The campaign was set up as a cooperative venture in which Intel reimbursed OEMs for a certain percentage of their advertising costs in return for using the "Intel Inside" logo in their advertisements and on the PCs themselves. By 1991, over 300 Intel customers were participating in the campaign. Nonetheless, at least some OEMs were concerned that "Intel Inside" would create a distinct brand identity for Intel that would undercut their own brands. Many felt threatened by the sheer scale of "Intel Inside;" between 1990 and 1993, Intel was reported to have spent over $500 million on the campaign.[48]

Intel addressed these concerns by insisting that the campaign was directed solely to end users and was intended to expand the total PC market. In 1994, Sally Fundakowski, Intel director of processor brand marketing, said that "when we started the campaign, end users weren't very aware of Intel at all. They didn't know we were a microprocessor company—or even what a microprocessor was."[49] Paul Otellini, senior vice president for worldwide sales, compared "Intel Inside" with other "classic ingredient brands," including Nutrasweet, Gore-Tex, and Dolby. "I don't believe that the Nutrasweet logo on Coke's can is destructive. The combination of the two is very powerful. That's been our idea from day one."[50]

By 1994, "Intel Inside" was expanded to include not just OEMs but software vendors as well. Intel asked software vendors to place a "Runs even better on a Pentium processor" sticker on PC software. "The software message becomes more important as software that takes advantage of Pentium becomes available," Sally Fundakowski said. "It would be easy just to talk performance [of microprocessors] until we were blue in the face."[51] The percentage of computer buyers preferring Intel rose from 60% in 1992 to 80% in 1993.[52]

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[48] Dan Steere, "Intel Corporation (D)," p. 8.

[49] Quoted by Nancy Arnott, "Inside Intel's Marketing Coup," *Sales and Marketing Management* (February 1994), pp. 78-81.

[50] Quoted by David Kirkpatrick, "Why Compaq is Mad at Intel," *Fortune* (October 31, 1994), pp. 171-178.

[51] Vincent Ryan, "Vulnerable Intel Leaves PC Innards Open," *Advertising Age* (November 14, 1994), p. S-12.

[52] Nancy Arnott, "Inside Intel's Marketing Coup," *Sales and Marketing Management* (February 1994), pp. 78-81.

Other microprocessor manufacturers responded to Intel's branding effort by denouncing the idea. In 1994, Steve Tobak, Cyrix's vice president of corporate marketing, said that "our customer is king. The customer is the one that needs to brand his product."[53] "There's nothing we can do in marketing that's as effective as what Intel's doing for us," said Steve Domenik, Cyrix vice president of marketing. OEMs "recognize us as a more natural strategic partner. They know we're not going to try to sell around them" to end users. According to Bob Kennedy, advertising manager for AMD, "end users are not concerning themselves with the brand of microprocessor. That's not realistic. We need to make people understand that the issue is compatibility with software, not with Intel. It shouldn't matter who makes the chip."[54]

Some of Intel's key customers initially resisted the "Intel Inside" program. For instance, in 1994, IBM and Compaq both opted out of the campaign. An IBM spokesman noted, "there is one brand, and it's IBM as far as IBM is concerned. We want to focus on what makes IBM computers different, not what makes them the same."[55] In September 1994, Eckhardt Pfeiffer, CEO of Compaq, warned, "Intel is at a crossroads. Either they learn to do the best thing for their customers or they will no longer be the primary supplier for this industry."[56] At the time, Intel's gross profit margins were at least twice that of Compaq and the other major PC manufacturers.[57]

In the end, the sheer weight of Intel's marketing efforts were enough to overcome the resistance by IBM and Compaq. In early 1996, Compaq completely reversed course on several fronts in its relationship with Intel. First, it signed a ten-year patent cross-licensing agreement with Intel which would enable the two companies to share information freely. John Rose, Compaq senior vice president and general manager for commercial desktop systems, said that "both companies spend a lot on R&D, and this eliminates the need to protect [information in] conversations. [It also means] we can move into new areas and markets. We have access to Intel technology, and they have access to ours." Secondly, Compaq agreed to purchase motherboards for Pentium Pro systems. Ross Cooley, Compaq senior vice president of Compaq North America, indicated that Compaq "will probably buy more if we believe that we can virtually outsource it from Intel and not have an advantage by doing it internally."[58] Finally, Compaq agreed to rejoin the "Intel Inside" campaign. In March 1997, IBM rejoined the campaign as well. A company spokesman announced that "IBM conducted new research, and it basically showed that participation in campaigns like this helps to communicate that IBM PCs are based on open standards as opposed to being proprietary technology. That is the major factor [in the company's decision to rejoin]."[59]

In 1997, it was reported that Intel would spend as much as $750 million worldwide on its marketing efforts. With IBM and Compaq back in, all top ten PC sellers and 1,400 total vendors worldwide had been signed up. The program included a 6% rebate on the price of Intel chips, with

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[53] Quoted by Joseph Epstein, " Why Andy Grove Should be Worried," *Financial World* (August 1, 1995), pp. 28-31.

[54] Vincent Ryan, "Vulnerable Intel Leaves PC Innards Open," p. S-12.

[55] Quoted in Bradley Johnson, "IBM, Compaq Tire of the 'Intel Inside' Track," *Advertising Age* (September 19, 1994), p. 52.

[56] Quoted by David Kirkpatrick, "Why Compaq is Mad at Intel," *Fortune* (October 31, 1994), pp. 171-178.

[57] Quoted by David Kirkpatrick, "Why Compaq is Mad at Intel," pp. 171-178.

[58] Quoted in Deborah DeVoe, "Compaq Buries the Hatchet with Intel," *Infoworld* (January 29, 1996), p. 25.

[59] Bradley Johnson, "IBM Moves Back to Intel Co-op Deal: Saw Disadvantage in Being Only PC Marketer not Using Program," *Advertising Age* (March 10, 1997), p. 4.

4% used to subsidize up to 66% of the cost of print ads featuring the Intel Inside logo and 2% used for up to 50% of broadcast ads.[60]

Intel's Systems Business

Although best known as a producer of computer components, Intel had been in the business of designing, manufacturing, and selling electronic sub-systems and even complete systems products. In the early 1970s, the "Systems Group" was formed to develop a series of computer-based instruments for simulating and testing Intel-based products.[61] As early as the mid-1970s, sales of such systems had become a significant source of profit for Intel. Later systems products included supercomputers and printed circuit boards that could be added to personal computers to enhance performance.[62] In 1987, the company began producing entire personal computers (not including the keyboard or monitor) which it sold to more than a dozen original equipment manufacturers, including AT&T, DEC, Olivetti, and Unisys. In the 1990s, Intel sold "motherboards" to a number of OEMs, including Dell, Hewlett-Packard, Gateway and Zeos. By 1990, Intel's system business accounted for 25% to 30% of the company's total revenues.[63] In 1994, Intel struck an agreement to sell 40,000-50,000 finished PCs per year to Reuters News Agency and to supply finished PCs to Carrefour, a French retailer. It was believed that Intel could sell complete PCs at roughly 25% less than major brands. A former Intel executive, speaking anonymously, said, "They've been schizophrenic for years about wanting to be in the end-product business. I think they continue to entertain the idea and are preparing for it, especially in the consumer market."[64]

Intel's systems business continued to grow dramatically for its sixth-generation Pentium Pro as the company integrated more and more system functions directly onto the processor and its supporting chips.[65] In January 1997, Intel reported that "for the Pentium Pro…the percentage of boards to processors was much higher than for Pentium processors, as would be expected when a new technology is introduced into the market."[66] According to John Hyde, technical manager for the Pentium Pro,

> . . . OEMs are happy to buy in at a higher level of integration and do their value-adds in cabinetry, software, memory configuration and add-in boards. Rather than design their own, they have come to us and…buy boards.[67]

New Product Introductions

When Intel introduced a new-generation microprocessor, PC makers were anxious to introduce new products with the latest design. As product life cycles for microprocessors shrunk, this initial demand became particularly pronounced (see **Exhibit 10**). However, because of the time required to ramp-up production to full capacity, new chips were typically in short supply during the first several

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[60] Bradley Johnson, "IBM Moves Back to Intel Co-op Deal," p. 4.

[61] Source: Professor Marco Iansiti, "Intel Systems Group," Harvard Business School case no. 691-040 , p. 3.

[62] Source: Professor Marco Iansiti, "Intel Systems Group," p. 3.

[63] Tom McCusk, "Intel Corp.," *Datamation* (June 15, 1990), p. 86.

[64] David Kirkpatrick, "Why Compaq is Mad at Intel," *Fortune* (October 31, 1994), pp. 171-178.

[65] Jaikumar Vijayan, " Intel Heads for Collision," *Computerworld* (May 8, 1995), p. 6.

[66] Intel news release, "Intel's 1996 Revenue and Earnings Set New Records," (January 14, 1997).

[67] Quoted by Fred Gardner and Kelley Damore, "Rift Between Intel, Compaq to Widen," *Computer Reseller News* (May 8, 1995), p. 3,145.

months after launch. Intel dealt with this issue in two ways. First, it priced new- generation chips at a premium in order to limit demand. High prices also enabled the company to generate profits early in the life cycle of a new product. David House, senior vice president of corporate strategy at Intel explained,

> The revenues on today's products have to pay for development tomorrow. We're spending about $2 billion this year on new products and new technologies. But competition clearly plays a role in the pricing process–I'm not going to deny that.[68]

With time, as massive production capacity would come on line, and as the threat of competition from clone microprocessors developed, the company would gradually reduce microprocessor prices.

A second device to balance supply and demand was to "allocate" supplies among OEMs. Putting customers on allocation was not a practice unique to Intel. In many industries, where similar capacity constraints arise, suppliers would ration supplies among customers based on various guidelines. Intel's policy was to use past buying behavior as a guide to determine how many chips a customer would receive when supplies were short.

Supplier Relationships[69]

With capital investments approaching $4.5 billion in 1997, Intel had become one of the world's largest purchasers of semiconductor manufacturing equipment. Intel's procurement strategy had evolved throughout the years. In 1985, the company adopted a policy of sole-sourcing critical pieces of equipment from the vendor offering the "best in breed" technology. This policy was driven by the desire to standardize process equipment as much as possible across different fabs. Standardization, in turn, was desirable because of the subtle but powerful effects different equipment designs could have on process performance. By standardizing equipment, the company hoped to facilitate the process of transferring technology and ramping-up production across facilities. Although this approach worked with regard to ramp-up and technology transfer, it created other problems often associated with sole sourcing arrangements. For instance, Intel found that sole-source suppliers tended to become less responsive to requests for technical support or improvement. Thus, in 1990, the company changed its policy again to allow dual-sourcing of critical pieces of production equipment.

Intel and the Internet

Intel's financial results had been nothing short of remarkable. (See **Exhibit 12**.) For 1997, analysts expected Intel to earn over $7 billion, challenging GE's status as the most profitable company in the United States. Its gross margin was reported to be around 60% in an industry that had grown more than 20% each of the last five years. Dataquest, a market research firm, predicted that Pentium Pro shipments would grow from 2.8 million units in 1996 to 25 million in 1997 and 65 million in 1998. By comparison, AMD and Cyrix were planning to double their shipments of Intel compatible microprocessors, from 4 million in 1996 to 8 million.[70] By 1997, Intel's capability to rapidly develop

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[68] David Coursey, "Intel Speeds Up the Chips, Slows Down the Clones," *Infoworld* (July 13, 1992), p. 94.

[69] Information for this segment was drawn from Gita Mathur under the supervision of Professor Robert H. Hayes, "Intel-PED (A)," Harvard Business School case no. 693-056.

[70] Dean Takahashi, "Intel's Net Doubles on Overseas Demand, " *Wall Street Journal* (January 15, 1997), p. A3.

and scale-up complex microprocessor production process, and to manufacture efficiently, were considered among the best in the world.[71]

With each successive generation of microprocessor, Intel had succeeded in placing more computing power on the desktops (and lap-tops) of individual computer users. Until the early 1990s, most observers concurred that the trend toward higher performing desktop computers would continue well into the future. However, the unexpected explosion in the use of the Internet created uncertainty whether Intel's technical trajectory would continue to be as lucrative as in the past.

In Grove's words, most PCs were intended for two basic uses: "the individual's own data and own applications" [the original desktop market] and "sending and sharing data to and with others"—the rise of "groupware" and other network communications such as e-mail. On these fronts Intel was undeniably competitive. But then, in Grove's mind,

> The Internet fosters the emergence of a third class of use: applications and data that are stored at some other computer someplace, prepared and owned by unrelated individuals or organizations, that anyone can access through this pervasive, inexpensive set of connections, the connection 'co-op.'[72]

Some believed that the Internet would soon allow individual users to tap into applications, data, and processing power through relatively simple and inexpensive desktop devices. Several companies were already developing strategies to push this alternative technical trajectory. A leader in this regard was Sun Microsystems, which had invented a programming language called Java that supports the development of applications (such as spreadsheets or wordprocessors) that could access processing power across the Internet. Sun had also introduced a relatively inexpensive "network computer" (NC)—a machine consisting of a keyboard, monitor, and a simple processor—that was designed to give users access to the Internet and the computing power that was available from remote servers. Sun's NC did not employ Intel's microprocessors or Microsoft's operating system.

As he assessed the potential impact of the Internet on Intel, Grove commented,

> I don't see that either our customers or our suppliers would be affected in a major way. What about our competition? There will be new players on the scene to be sure, but they are just as likely to play the role of complementors as competitors. [At the same time,] companies that used to be complementors to our competitors are now generating software that works as well on computers based on our microchips as on computers based on others. That makes them our complementors too. Also new companies are being created almost daily to take advantage of the opportunity provided by the Internet. Creative energy and funds are pouring in, much of which is going to bring new applications for our chips. All this suggests that the Internet is not a strategic inflection point for Intel. But while the classic signs suggest it isn't, the totality of all the changes is so overwhelming that deep down I think it *is*.[73]

Grove therefore saw the Internet as having the potential to represent a "10X" change for Intel's business. (See **Exhibit 13**.) To hedge its risk, Intel had invested a half-billion dollars in venture capital, taking equity positions in over 50 companies, many of which were involved in Internet technologies. Grove explained:

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[71] M. Iansiti and J. West, "Technology Integration: Turning Great Research into Great Products," *Harvard Business Review*, May-June 1997 (reprint #97304).

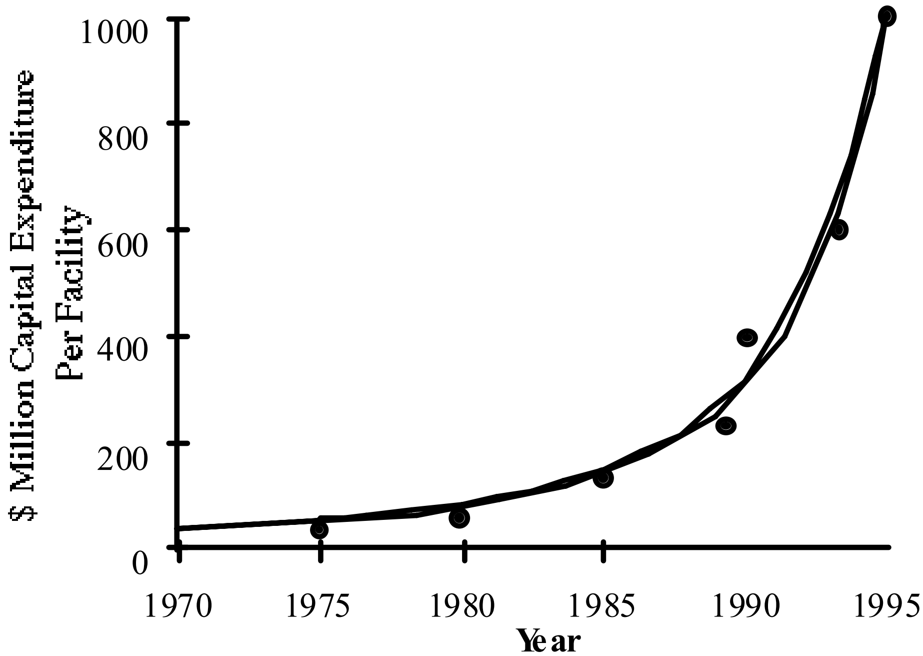
[72] Andrew S. Grove, *Only the Paranoid Survive*, (New York: Currency/Doubleday, 1996), p. 179.

[73] Andrew S. Grove, *Only the Paranoid Survive*, p. 181.

> Very simply, we are a growth company. Our whole culture, our whole technical culture, our whole management culture depends on that. At the same time, you cannot guarantee me no one is sneaking up on me even in today's PC environment. The only advantage Intel has is that we have been faster to get to some places than other people have. That implies we have places to go. If I don't have places to go, I lose time as a competitive advantage. So give me a turbulent world as compared with a stable world and I'll want the turbulent world.[74]

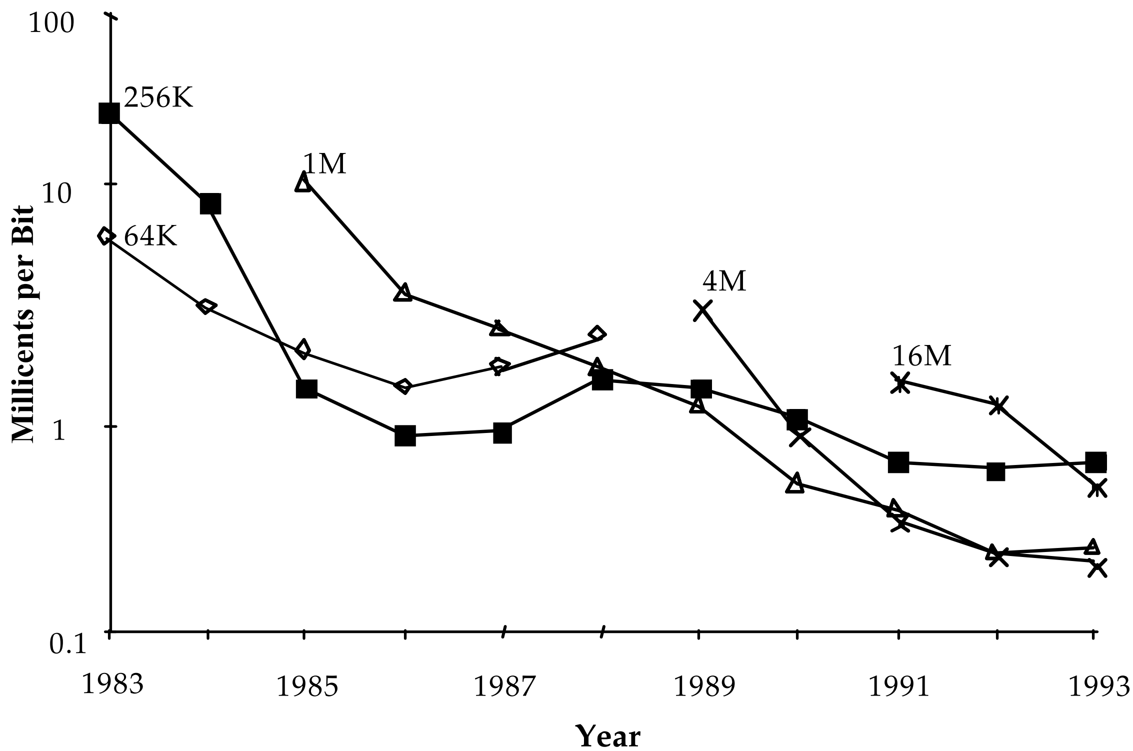
[74] Quoted in Rich Karlgaard and George Gilder, "Talking with Intel's Andy Grove," *Forbes* (ASAP supplement), February 26, 1996, p. 63.

Exhibit 1 Capital Cost Per Semiconductor Manufacturing Facility



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 2 Price Trends in DRAMs (Source: same as **Exhibit 1**)



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 3 Volume Trends in DRAMs (Source: same as **Exhibit 2**)

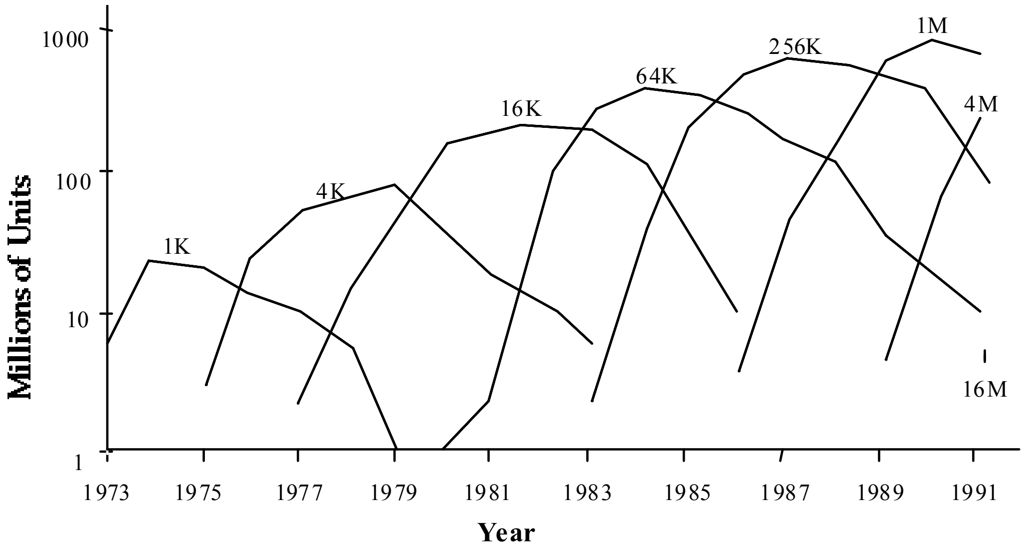


Exhibit 4 Top Ten Manufacturers of DRAMs and SRAMs, 1984

Company	Market Share (percent)
1. Hitachi	15.1
2. NEC	13.0
3. TI	10.8
4. Fujitsu	7.8
5. Toshiba (tie)	7.1
5. Mostek (tie)	7.1
6. Motorola	6.1
7. Mitsubishi	4.0
8. Intel	3.4
9. National	1.1

Source: George W. Cogan, "Intel Corporation (A): The DRAM Decision," Graduate School of Business, Stanford University case BP-256A, p. 26. Numbers are from Dataquest and annual reports.

Exhibit 5 The DRAM Market: Worldwide Volumes and Intel's Share, 1974-1984

	DRAM Volume (Total Unit Shipments, 000s)	Intel's Market Share (percent)
1974	615	82.9
1975	5,290	45.6
1976	28,060	19.0
1977	59,423	20.0
1978	97,976	12.7
1979	140,064	5.8
1980	215,676	2.9
1981	247,144	4.1
1982	394,900	3.5
1983	672,050	3.6
1984	1,052,120	1.3

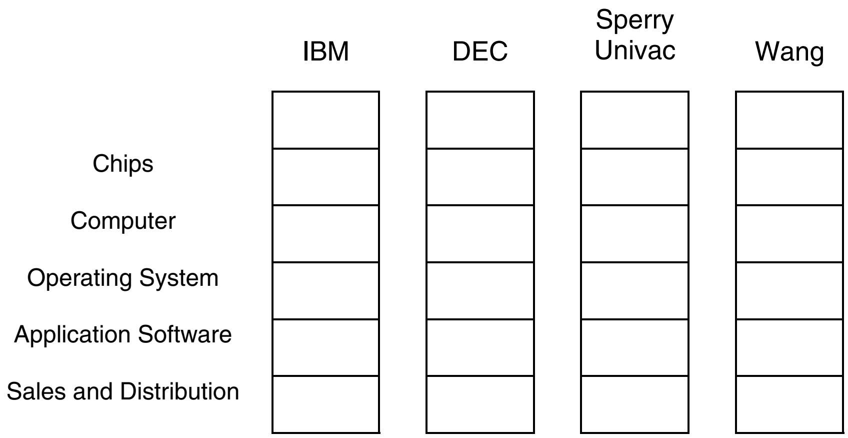
Source: Robert A. Burgelman, "Fading Memories: A Process Theory of Strategic Business Exit in Dynamic Markets," *Administrative Science Quarterly* 39 (1994), p. 37. Figures quoted are from Dataquest.

Exhibit 6 The Top Five PC Manufacturers, by Revenue ($M)

1991		1992		1993		1994		1995	
1. IBM	8.5	1. IBM	7.7	1. IBM	9.7	1. Compaq	9.0	1. IBM	12.9
2. Apple	4.9	2. Apple	5.4	2. Compaq	7.2	2. IBM	8.8	2. Compaq	9.1
3. NEC	4.1	3. Compaq	4.1	3. Apple	5.9	3. Apple	7.2	3. Apple	8.5
4. Compaq	3.3	4. NEC	4.0	4. Dell	2.6	4. Dell	2.9	4. Fujitsu	6.4
5. Fujitsu	2.3	5. Fujitsu	2.6	5. AST	2.0	5. Gateway	2.7	5. Toshiba	5.7

Source: *Datamation*, June 15, 1992-1996

Exhibit 7 The Old Vertical Computer Industry—Circa 1980



Source: Andrew S. Grove, *Only the Paranoid Survive* (New York: Currency/Doubleday, 1996), p. 40.

Exhibit 8 The New Horizontal Computer Industry—Circa 1995 (not to scale)

<table>
<tr><td>Chips</td><td colspan="3">Intel Architecture</td><td>Motorola</td><td colspan="2">RISCs</td></tr>
<tr><td>Computer</td><td>Compaq</td><td>Dell</td><td>Packard Bell</td><td>Hewlett-Packard</td><td>IBM</td><td>Etc.</td></tr>
<tr><td>Operating System</td><td colspan="2">Dos and Windows</td><td>OS/2</td><td>Mac</td><td colspan="2">UNIX</td></tr>
<tr><td>Application Software</td><td colspan="3">Word</td><td>Word Perfect</td><td colspan="2">Etc.</td></tr>
<tr><td>Sales and Distribution</td><td>Retail Stores</td><td colspan="2">Superstores</td><td>Dealers</td><td colspan="2">Mail Order</td></tr>
</table>

Source: Andrew S. Grove, *Only the Paranoid Survive* (New York: Currency Doubleday, 1996), p. 42.

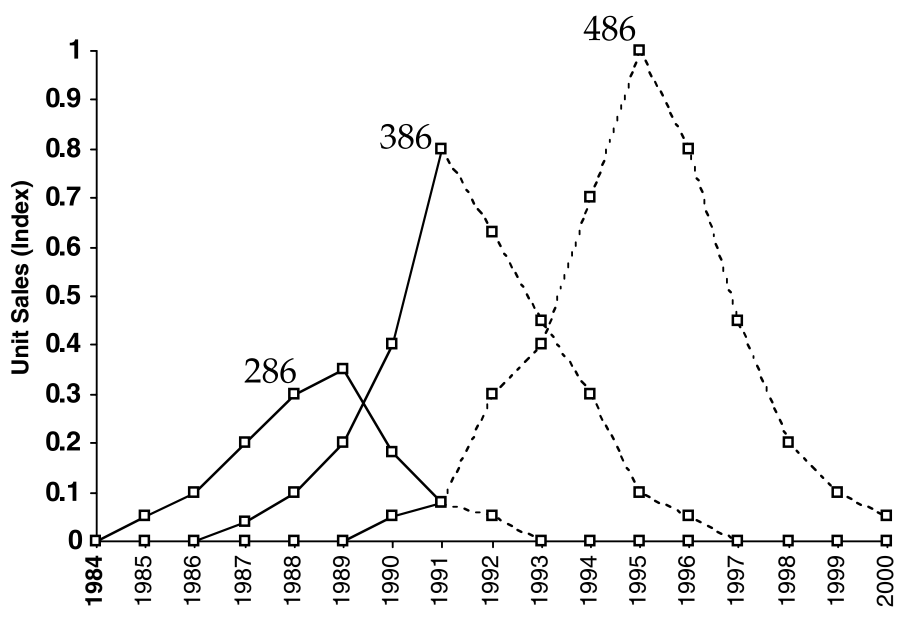
Exhibit 9 Worldwide PC Unit Shipments by Processor Type (000s)

	8088/86	286	386	486	PC Total	680X0	All RISC
1981	72				72	5	
1982	324				324	18	
1983	1135				1135	66	
1984	2894	61			2995	665	
1985	3626	610			4236	626	
1986	4289	1875	42		6206	919	1
1987	5139	4387	449		9975	1564	5
1988	5633	6652	1445		13729	2048	21
1989	4221	8284	3391	5	15901	2443	80
1990	2633	7968	7691	162	18455	2883	195
1991	1174	5318	12442	1162	20096	3363	323
1992	526	2847	13865	4523	21760	3865	448

—PC total includes all Intel and Intel-compatible microprocessors.

Source: Dan Steere, "Intel Corporation (D): Microprocessors at the Crossroads," Graduate School of Business, Stanford University Case BP-256D, Exhibit 8, p. 27. Numbers are from International Data Corporation.

Exhibit 10 Product Lifecycles for Successive Generations of Microprocessor Chips (Estimates and Projections)



486 Peak Sales = 1.0

Source: Gita Mathur under the supervision of Professor Robert H. Hayes, "Intel PED (A)," Harvard Business School Case no. 693-056.

Exhibit 11 Price and Characteristics of Intel Processors

	Release Date	Price at Launch	1993 Price	Transistor Count
8086	Jun. 1978	$360	Discontinued	29,000
80286	Feb. 1982	$360	$8	134,000
80386	Oct. 1985	$299	$91	275,000
80486	Aug. 1989	$950	$317	1,200,000
Pentium	Mar. 1993	$995		3,100,000

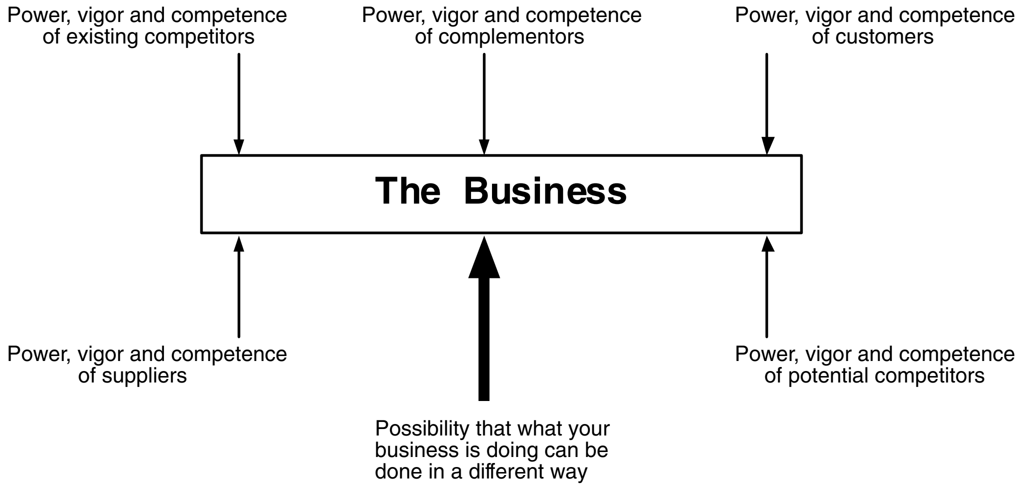
Source: Dan Steere, "Intel Corporation (D): Microprocessors at the Crossroads," Graduate School of Business, Stanford University Case BP-256D, Exhibit 8, p. 24. Numbers from *BYTE*, May 1993.

Exhibit 12 Intel's Financial Results (Employees in thousands; all others in $millions)

	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

Source: Company Reports.

Exhibit 13 Six Forces Diagram—With a "10X" Force



Source: Andrew S. Grove, *Only the Paranoid Survive* (New York: Currency/Doubleday, 1996), p. 30.

Glossary

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

Dynamic Random Access Memory (DRAM): A type of semiconductor that provides Random Access Memory (RAM) for the microprocessor. They are called "dynamic" because the information they carry has to be continuously "refreshed" from permanent storage.

Static Random Access Memory (SRAM): A second type of Random Access Memory (RAM) semiconductor which does not require refreshing as long as power is constantly applied. In general, SRAMs are faster than DRAMs but take up more space and are more costly to manufacture. Microprocessors themselves usually carry some on-chip memory in SRAM form.

Motherboard: A computer's main circuit board, which includes the microprocessor and RAM.

Bipolar: Refers to a generic type of transistor and to the family of processes used to make it. The bipolar transistor consumes more power than the MOS transistor, but can be made to switch faster. The bipolar process is a relatively complex semiconductor process.

Complementary Metal Oxide Semiconductor (CMOS): Refers to a semiconductor process used to produce chips which have the advantage of very low power consumption. Laptop computers use exclusively CMOS integrated circuits.

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

Photolithography: The optical imaging process whereby circuits are imprinted onto silicon wafers to make semiconductors.