



STANFORD

GRADUATE SCHOOL OF BUSINESS

CASE: IB-70
DATE: 08/25/09

SAMSUNG ELECTRONICS GLOBAL FLASH MEMORY MARKET

INTRODUCTION

In 2006, Samsung Electronics semiconductor business was the world's largest supplier of flash memory components, with 42 percent share in the fast-growing NAND flash market. The company, however, did not originally invent flash technology and entered the market in the early 1990s behind technology leader Toshiba Corporation of Japan. Nevertheless, Samsung set a bold objective at the time of eventually overtaking Toshiba for the number one position, which it saw as critical for the company's long-term success. Over the next fifteen years, Samsung pursued this goal with fierce dedication, all the while navigating an unproven market with highly cyclical characteristics, before eventually succeeding.

In 2006, demand for flash was strong and the market was expected to continue growing at a rapid rate. In order to hold onto its dominant market share, the company would need to invest significant amounts of capital into new production facilities. Such an investment would constitute a large risk for the company and could threaten the balance of the larger Samsung Group. The leaders of Samsung Semiconductor Division were faced with a difficult decision, one that would have great implications not only for their technological leadership position but also for the future success of the company.

SAMSUNG ELECTRONICS, SEMICONDUCTOR DIVISION

Overview

Samsung Electronics Company was the largest company within the Korean Samsung Group conglomerate (referred to as a *chaebol*), with 2005 consolidated revenues of \$79.6 billion. This

Professor Bruce McKern and Brian Tayan prepared this case as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation. Research for this case was supported in part by the Hoover Institution.

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compared to \$22.8 billion in revenues for Samsung Life Insurance, the second largest company, and \$9.7 billion for Samsung Corporation (engaged in trading and construction to support the development of the Korean national economy), the third largest (see **Exhibit 1** for information on the companies comprising Samsung Group).¹

Samsung Electronics Company consisted of five main businesses: telecommunications network, semiconductor, digital media, liquid crystal display (LCD), and digital appliance. In 2005, Samsung semiconductor business contributed 72 percent of Samsung Electronics' \$7.9 billion in operating profit² (see **Exhibits 2 and 3** for product and financial information for Samsung Electronics).

History³

Samsung first entered the semiconductor industry through the acquisition of Korea Semiconductor Company in 1974. Korea Semiconductor had been established a few years earlier by engineers trained in the United States who wanted to bring semiconductor manufacturing to Korea. The original venture, however, ran into financial difficulty and Samsung Electronics, which was a customer of Korea Semiconductor and used its components in television sets, electronic watches and appliances, purchased the company to ensure continued supply. In the first few years of operating the semiconductor subsidiary, Samsung struggled with quality control issues, having little institutional knowledge in the manufacture of semiconductors.

In the late 1970s, Byung-Chul Lee, then chairman of Samsung Group, decided that it was strategically important for Samsung semiconductor business to increase its technical expertise. The company actively contacted Japanese engineers with a deep knowledge of semiconductor design and process engineering to train Samsung employees. A large number of Japanese engineers visited Korea to transfer knowledge of clean room operation and quality control. With their assistance, Samsung began to improve its manufacturing yield and operating profitability. In 1982, Samsung semiconductor business generated its first profit.

In the 1980s, Samsung set its sights on the production of a more sophisticated semiconductor, the DRAM memory chip used in computers (see **Exhibit 4** for definitions of semiconductor technology). The company recruited Korean-American engineers with experience working for semiconductor manufacturers in the United States. Samsung also purchased basic DRAM designs from Micron, a DRAM company based in the U.S., and began construction of its first fabrication plant in 1983. Samsung believed that in order to catch up with competitors, it needed to complete construction in less time than the industry average of two to three years. By

¹ Samsung Group, "2005 Annual Report," 2006, <http://www.samsung.com/Aboutsamsung/samsunggroup/AnnualReport/AnnualReport/index.htm>, (August 31, 2006).

² Samsung Electronics Company, "2005 Annual Report," 2006, <http://www.samsung.com/Aboutsamsung/electronicsglobal/InvestorRelations/FinancialInformation/AnnualReport/index.htm>, (August 31, 2006). Operating profit at the parent level from 2005, converted to U.S. dollars at exchange rate 1,024.31 Korean Won / U.S. Dollar.

³ This section draws upon material from "Samsung Electronics' Semiconductor Division (A)," GSB No. IB-24A, pp. 5-8.

concurrently managing the planning, design, and construction phases of the project and by working 24 hours per day, Samsung was able to open its first fabrication plant within six months.

Samsung further closed the production gap with competitors by focusing on the latest generation technology. In 1984, Samsung dedicated manufacturing lines to six-inch wafers, when industry leaders such as Intel, National Semiconductor, and NEC produced six-inch wafers only on pilot lines. Although the company faced quality problems and initially low yields, Samsung increased its production efficiency over time by systematically improving the manufacturing process. With each new generation of technology, Samsung's market position improved. By 1992, Samsung had become the worldwide market leader in DRAM, with a market share of 13.6 percent. By 2005, eleven years later, Samsung semiconductor business became the largest producer of semiconductor-based memory, including DRAM, SRAM, NAND flash and multi-chip packages with revenues of \$15.7 billion.

ELECTRONIC MEMORY MARKET⁴

Samsung's achievement in entering the flash memory market needs to be understood in the context of the technical characteristics of the electronic memory business. This section provides a brief overview of the technology.

The electronic memory industry was highly competitive and characterized by strong growth and high cyclicity. Strong demand for storage of both corporate and consumer electronic data in the form of data files, audio and video content, as well as stored settings on consumer products, led to rapid industry-wide revenue growth in the 1990s and 2000s. Customer demand for improved capacity, continually changing technological standards, and constant price deflation meant that manufacturers of memory storage devices needed to innovate continuously, watch consumer trends, and manage production costs carefully. Slowdowns in economic growth and errors in budgeting production capacity could lead to sharp cyclical reductions in revenues and profits.

The basic unit of electronic memory was the "bit." A bit (short for "binary digit") referred to the storage of information in a system of two possible values represented as either a 0 or a 1. Strings of data were stored in electronic memory devices as a series of bits, enabling the formation of Boolean logic chains. These strings were read by the central processing unit of a computer which recreated the logic chain of the stored information and executed its instructions.

Although a bit was the basic unit of memory, the total storage capacity of an electronic memory device was often quantified in terms of "bytes" (1 byte equaled 8 bits). For example, a device that contained 8 bits of information was described as having 1 byte of storage capacity. 1000 bytes equaled 1 kilobyte (KB); 1000 KB equaled 1 megabyte (MB); and 1000 megabytes equaled 1 gigabyte (GB).

In 2006, there were three main types of memory storage: magnetic, optical, and solid-state (semiconductors). Magnetic memory stored data in bits through the alignment of particles on a

⁴ Unless otherwise noted, information from Standard & Poor's Industry Survey: Semiconductors, November 16, 2006.

disk surface. The closer together the particles were placed on the magnetic surface, the higher the storage density. Because magnetic storage was inexpensive to produce and could be erased and rewritten easily, this type of memory was used in the computer hard disk drive. By 2006, the standard hard drive of a personal computer was 100 gigabytes and the retail cost had fallen to approximately \$100.⁵

Optical memory stored data in pits burned by a laser onto the surface of a compact disk (CD) or digital video disk (DVD). The CD or DVD player read the information by using a laser to reflect light from the pits. Optical memory allowed much higher densities of data to be stored per unit of surface area, making it better suited for long-term retention of computer data. However, because data was burnt into the disk surface, it was less suitable for continuous erasing and rewriting of data. In 2006, Toshiba announced that its researchers had created a DVD prototype with capacity to hold 30 gigabytes of data.⁶

Solid-state memory (semiconductors) stored data in transistors that were embedded on an integrated circuit chip. Each transistor was in one of two electrical states (“charge” or “no charge”) which represented bits of information. Storage capacity was increased through smaller linewidths (the size of the transistor) and greater circuit density (number of transistors per chip). The storage capacity of each chip was described in terms of the number of bits it could hold, such as a 16 megabit chip. More than one chip could be added to each storage device to create its total storage capacity, which was quantified in terms of bytes; for example, four 16 megabit chips could be combined to create a device with 8 megabytes of capacity.

The observation that semiconductor capacity improved over the years was known as Moore’s Law, named after Gordon Moore, co-founder of Intel. In 1965 Dr. Moore observed that researchers had been able to double the number of transistors on a chip every year. Dr. Moore accurately predicted that this trend would continue. In 1975, he modified his prediction for slower growth, and circuit density continued to double every 18 months through 2006.

Semiconductor memory was categorized as either volatile or non-volatile. Volatile memory, also known as RAM (random-access memory), could be changed or reprogrammed but the contents were lost when power was interrupted. Non-volatile memory, known as ROM (read-only memory), did not lose its contents when power was interrupted but could not be reprogrammed. Non-volatile memory was less capable of fast data writing.

Volatile Memory

Volatile memory was used as an active storage memory for computers connected to a power source. In 2006, the cheapest and most common type of memory used in computers was DRAM (dynamic random-access memory). The term “random access” meant that the data in any part of the memory could be accessed at any time; access did not require the sequential reading of data from a specified starting place. In 2006, the standard memory capacity for a DRAM component

⁵ Philipson, Graeme, “Disk drive’s future not too flash,” *The Age*, June 6, 2006.

⁶ “Compact Disc,” Wikipedia, http://en.wikipedia.org/wiki/Compact_disc; “DVD,” Wikipedia, <http://en.wikipedia.org/wiki/DVD>.

was 512 megabits, with developers working toward the mass production of the gigabit DRAM chip.⁷

Another type of volatile memory, SRAM (static random-access memory) was used in computer cache memory. Because SRAMs did not need to have their storage cells refreshed, they could operate at higher speeds. SRAMs were faster and more intricate than DRAMs, making them more costly to produce, but both products had essentially become commodities by 2006.

Non-Volatile and Flash Memory⁸

Non-volatile memory was used as the computer memory that allowed a computer to execute program files during the boot-up process. In early PCs, boot-up programs were stored on floppy disks that had to be inserted into the computer, but by the 1990s ROM (read-only memory) programs were built into the computer system. Unlike RAM (random access memory), ROM was not lost when the computer power was turned off.

Flash memory was a remarkably versatile form of non-volatile semiconductor, which retained information without power (like ROM) and could be erased and reprogrammed (like RAM). Predecessors to flash memory were first invented in 1967 by researchers at Bell Laboratories, who added a second floating gate to trap electrons in a transistor when power was turned off. By running a certain voltage across the transistor in the opposite direction, the transistor would be reset to its original state and ready for reprogramming.

In 1980, researchers at Toshiba advanced this technology by creating chips that allowed fixed blocks of information rather than individual bytes to be erased and rewritten, a process that greatly increased recording speeds. They called the technology “flash memory.” In 1986 Toshiba produced the first batch of flash memory chips, which they called NOR flash. NOR flash could read data at relatively fast speeds. By 2006, NOR flash was used to store executable code for mobile devices such as cell phones and personal digital assistants (PDAs).

In 1987, the same researchers who developed NOR flash technology developed the concept of a new type of flash memory, called NAND flash. The names NAND and NOR, which were derived from different Boolean logic operations, reflected the different ways in which memory components were connected. NAND flash could write data at relatively fast speeds.

Flash Memory Products⁹

By 2006, flash memory was competing aggressively in markets that were previously the domain of the hard disk drive and optical disc. Flash was used in digital cameras to store photographs, in USB memory sticks, and MP3 players. Flash was also used to store settings and configuration data in automobiles, video game consoles, and other devices with electronic components.

⁷ Gaudois, Nicolas et al, “Global Semiconductors: Semis cycle to trough by 1H07,” Deutsche Bank Europe Equities, September 19, 2006.

⁸ “Not just a flash in the pan - case history,” *The Economist*, March 11, 2006.

⁹ Ibid, loc. cit.

A USB memory stick in 2006 could hold 1 gigabyte of data, comparable to approximately 700 floppy disks, at a retail price of \$50 per gigabyte. Low cost, small size, and substantial storage capacity allowed this technology to render obsolete the floppy disk and burnable CD as methods of transferring and storing information for personal computers.

Through use in MP3 players, flash memory also began to replace CDs as a standard musical storage technology. In 2006, the iPod nano, an MP3 player produced by Apple Computer Company, contained 4 gigabytes of storage capacity, capable of holding 1,000 songs. By comparison, the standard audio CD could store only 17 songs. MP3 players powered with flash technology were substantially smaller and required less battery power than CD players, adding to consumer appeal. Within the MP3 market, however, the hard disk drive still retained a substantial cost advantage over flash technology. In 2006, for example, a 30 gigabyte iPod with hard disk drive cost \$299 versus \$249 for the 4 gigabyte iPod nano with flash memory.

Flash memory manufacturers were working hard to make their technology competitive with hard disks as the standard storage technology in laptops. However, the price differential between a gigabyte of hard disk drive versus a gigabyte of flash memory meant that in 2006 a flash-memory based computer would still be considerably more expensive. Flash memory chips were, nevertheless, declining in price at a rate of 50 percent every year, indicating that they might be competitive with hard disk drives before long.¹⁰ Since flash memory contained no moving parts, it had the advantage of being more robust than the hard disk drive.

SAMSUNG GROUP¹¹

The Samsung Group had a long history and considerable experience in managing commodity businesses. In 1953, the company, founded by Byung-Chul Lee, made its start as a sugar refiner. The next year it entered textile manufacturing and soon added property and casualty insurance and life insurance operations.

For many years, the Samsung Group benefited from close relations with the Korean government. Following the Korean War, the government relied on Samsung and other *chaebol* to bring economic development to the country. Together the leaders of the *chaebol* worked with government officials to develop a strategic plan for the economic development of the country. Samsung group entered diverse business lines, including paper manufacturing, construction, shipbuilding, and electronics, which would bring economic growth to Korea. Because the government offered financial subsidies to the *chaebol* to encourage their expansion, they entered diverse business lines in rapid succession with little incentive to focus on operating efficiencies in existing businesses. In 1959, Chairman Lee established a headquarters office to make strategic decisions about entry and expansion into new businesses.

For many decades, the *chaebol* used profits from more efficient businesses to support other group companies facing financial difficulty. The Asian Financial crisis of 1997 brought a

¹⁰ Ramstad, Evan, "Samsung is Lifted by Big Chip Order for New iPod Nano," Wall Street Journal, September 13, 2005

¹¹ For more information on Samsung Group history, see "Samsung and Daewoo: Two Tales of One City," HBS No. 9-804-055.

change to these and other business practices. In order to bring economic stability and increase investor confidence in the Korean economy, the government began to enforce regulations that the *chaebol* operate their subsidiary companies as legally independent entities. In addition, one of the conditions of the bailout of the Korean economy by the International Monetary Fund was that barriers to foreign ownership be reduced. As a result, the practice of transferring funds between *chaebol* companies was eliminated. Group companies were forced to become self-sufficient, although they still operated under the strategic direction of the group headquarters.¹²

Samsung Group Headquarters

The Samsung Group operated under the philosophy that its corporate headquarters could provide the strategic direction and analytical research to identify new businesses and direct the resources necessary for initial investment. Resource allocation to both new and existing businesses was decided according to three value disciplines: product leadership, operational excellence, and customer intimacy¹³. In addition, each business was expected to exceed a hurdle rate for return on investment.

The headquarters performed its analysis in a collaborative effort with the managers of the Samsung businesses. Dr. Soon-Bong Yoon, Senior Executive Vice President at Samsung Economic Research Institute, described this strategic planning process as “middle-up-down management”¹⁴:

Chairman Lee shows us the vision and the big picture for direction. Then, the middle managers generate the various ideas about that vision. The Chairman’s headquarters evaluates those ideas and selects among them. If an idea is selected, a real business is started. And that’s the key point of the centralized leadership and decentralized managers. We have both advantages.¹⁵

The headquarters benefited from its ability to look across a greater breadth of the organization than was available to each business unit president. Once an idea was funded, however, the leader of that business was entirely responsible for execution. Most strategic and tactical decisions, including subsequent investments, were decided by the president of the business, who operated for the most part autonomously.

Dr. Yoon described middle-up-down management as a four-part, self-reinforcing system. The first driver of the system was the *intuitive wisdom* of the chairman, whose vision drove the long-term direction of Samsung Group. The group headquarters compiled extensive analysis and made recommendations on strategic direction, but it was the intuition of the chairman, developed

¹² GSB No. IB-24A, pp. 7-8.

¹³ The concept of the three value disciplines is detailed in: Michael Treacy and Fred Wiersema, *The Discipline of Market Leaders: Choose Your Customers, Narrow Your Focus, Dominate Your Market*. Reading, MA: Addison-Wesley, 1997.

¹⁴ The concept of middle-up-down management is detailed in: Ikujiro Nonaka and Hirotaka Takeuchi, *The Knowledge-Creating Company*, New York: Oxford University Press, 1995.

¹⁵ Quotations from Dr. Soon-Bong Yoon, Senior Executive Vice President, SERI, from case writer interviews July 14, 2006.

over many years, which selected the future direction of Samsung. Dr. Yoon used Samsung's semiconductor division as an example of managing with intuition:

The investment for a semiconductor fabrication plant costs several billion dollars. It takes about one to two years to construct one factory. If the demand forecast is not clear at the time, the investment decision is very difficult. At that time, the owner's intuition can be critical for the investment.

Dr Yoon agreed that intuition was difficult to define, but that it meant an ability to make sound judgments leading to decisions, without necessarily articulating a transparent logical path. It was based on experience and the ability to recognise patterns that had occurred before and understand the potential for their future application.

The second driver was *ownership management*, meaning that investment decisions were made by the chairman, who had a significant ownership of the *chaebol*. Samsung believed there were benefits of having ownership and management held by the same person, one of which was that decisions could be made quickly. Because one of Samsung's core values was product leadership, first-mover advantage was highly valued. Dr. Yoon explained:

[In the early 1990s], we caught up with NEC in the DRAM market by developing the 4 megabit DRAM. NEC and Samsung made the decision to invest at the same time. But NEC had to borrow money from Sumitomo Bank. The process took so long, maybe a year or more. Samsung was able to invest immediately. The key point was the speed, the short funding time, which resulted from ownership management.

The third driver was *portfolio management*, which protected the Samsung Group in case the decision-making of the headquarters was mistaken. Diversification of the investment portfolio ensured that Samsung Group's capital was not overly concentrated in one area, to the extent that its failure would bring down the entire organization. According to Dr. Yoon, Samsung referred to portfolio management as "flying geese management," referring to the fact that "when geese fly, they don't fly alone; they fly together" and take direction from the front¹⁶.

The fourth driver was *core competency management*¹⁷, the principle that funds would only be made available for businesses which were based on Samsung's core competencies. Core competency management would protect Samsung Group against entering businesses without the necessary management strengths to be competitive.

¹⁶ The flying-geese model was first used to describe the life cycles of industries in the course of economic development (Akamatsu, 1962), with the focus on specific industries in specific countries. Subsequently, it was extended to study the dynamic changes in the industrial structure (that is, the rise and fall of different industries) in specific countries, and further to the shift of industries from one country to another. See Kaname Akamatsu, "A Historical Pattern of Economic Growth in Developing Countries," *The Developing Economies*, 1962.

¹⁷ The concept of core competency management is detailed in: Gary Hamel and C.K. Prahalad, *Competing for the Future*, Boston, Mass: Harvard Business School Press, 1994.

As a result of the portfolio approach and the core competency discipline, the businesses were implicitly in competition with each other for funding and would receive the additional capital required to grow only if they could demonstrate a track record of success.

Together, Dr. Yoon believed that “these four management elements comprise a positively reinforcing system” and that this self-reinforcing system was critical in the success of the semiconductor business.

SAMSUNG’S ENTRY INTO FLASH MEMORY

Having achieved market leadership in DRAM production by the late 1980s, and facing slowing demand, researchers at Samsung concluded that they needed a new technology to continue Samsung’s growth in the semiconductor industry. They recognized that global competition for DRAM production was intensifying and that the product was increasingly becoming a commodity. Without a new technology, Samsung’s long-term profitability was at risk.

According to Dr. Kangdeog Suh, Senior Executive Vice President of Flash Research & Development in the Memory Division:

In order to expand the business we had to find something other than the DRAM. We had to find new technology to survive. We were DRAM engineers; our expertise was in DRAM. But that didn’t stop us from moving into new technologies. Our first technology was EPROM and EEPROM.¹⁸

Both EPROM and EEPROM were predecessor technologies to flash memory, but each had deficiencies which made commercialization for consumer products difficult. EPROM (erasable programmable read-only memory) required two separate devices for rewriting, which made the process tedious. With EEPROM (electrically erasable programmable read-only memory), rewriting could be done on a single device, but it was expensive. As a result, the market size for EPROM and EEPROM was relatively small, and the company continued to search for new technologies.

In 1989, Samsung realized a technological breakthrough had been made when an article appeared in an industry journal written by researchers at Toshiba describing a storage memory that could rewrite information as quickly as volatile memory and still retain information when removed from a power source. The new device was called flash memory. The chief researchers at Samsung thought it was a promising idea, and knew that it built upon the technological capabilities used in EPROM and EEPROM. However, they did not have detailed specification on how to develop the technology.

Fortunately for Samsung, Toshiba discovered that, even though the new technology was promising, it could not garner enough commitments from consumer electronics companies, which were hesitant to adopt a new technology that was reliant upon a single manufacturer.

¹⁸

Quotations from Dr. Kangdeog Suh, Senior Vice President for Research & Development, Memory Division, Samsung Electronics from case writer interviews July 13, 2006.

They were afraid of being locked in with a sole vendor with exposure to unilateral price markups. Without sufficient customer demand, Toshiba found itself unable to bring the technology to market. As a result, in 1993, Toshiba had to look for a partner with which to collaborate in the development and marketing of flash technology. They chose Samsung, which possessed the technological capabilities to be their partner, and both companies agreed to develop common specifications to encourage market reception of the product. According to Dr. Suh:

Toshiba didn't have any working product at the time. They had product specifications, but no product. They agreed, however, to share the specifications with us, but we were to each work separately on developing the technology. Competitive and design details were not shared. Our engineers met with them, each quarter, to discuss progress. Toshiba had a lead in exploring this technology, but we thought that we could catch up.

Samsung researchers recognized that they were starting behind Toshiba, but they were confident that over time, with a focused and diligent approach, they could close the gap. They had confidence that the success they achieved in dominating the DRAM market could be replicated over time to help them become a leader in flash memory. Dr. Suh described the development process:

This was an exciting time for the company. Technically, flash was an entirely new idea. We were proving that the idea would work. We had to design the chips with a new concept. There were many new concepts, new ideas, and at the time digital technology was not very mature, so there was a lot of trial and error. It took us many years, almost four years to make our first chip.

Toshiba had a one to two year head start in designing flash memory semiconductors and patents to the basic technology that Samsung was required to license. Nevertheless, Samsung overcame its early disadvantage, collecting information to track Toshiba's progress and modifying its own internal targets to keep pace with its number one competitor. The pressure to keep up with Toshiba was a strong motivating factor for Samsung engineers, and in 1994 the company succeeded in producing a 16 megabit NAND flash chips at the same time as Toshiba.

The initial market for NAND flash was modest, and Toshiba had more than a 50 percent share. At first, NAND flash was used in industrial applications, such as outdoor meters. The first consumer product was a digital answering machine. Samsung believed, however, that eventually there would be broad consumer applications for NAND flash, including replacement of the hard disk drive of personal computers. In pursuit of this long-term goal, it focused on improving NAND flash cost and efficiency to make it suitable for this market.

In 1996, the first digital camera designed for consumer use came on the market, the QV 10 Casio camera with 32 megabit storage capacity. Because of its low image resolution and memory, the camera was not broadly adopted. The mass market for digital cameras did not begin to take off until the 128 megabit digital camera was introduced in 1998. By that time, Samsung had greatly improved its technological and manufacturing capabilities in NAND flash. Still, the initial

market for NAND flash memory before 2000 was still less than 10 percent of the size of the DRAM market.

Toshiba, recognizing that Samsung was quickly catching up, approached its rival about a joint venture. The terms of the proposal, however, were unfavorable to Samsung, and the company felt that entering into such a partnership would limit its future growth. After reviewing their manufacturing costs, their technological competitiveness, and other strategic issues relative to Toshiba, they decided that Samsung should continue to develop the technology on its own. The decision was risky, because the majority of Samsung's semiconductor profit came from DRAM. A commitment to flash technology would require reallocation of resources away from DRAM, including very expensive fabrication lines and engineers. However, the company recognized that its future relied not only on the successful development of flash but on Samsung's taking over leadership in the technology. Furthermore, it was not Samsung's way to operate in joint ventures. Samsung excelled in independent operations, relying on internal, rather than external, collaboration among its engineers. So, by 2000, the company committed itself to the solo development of flash technology, aiming to be the market leader.

The decision paid off handsomely. By 2005, the global flash memory market had grown to \$19 billion, more than double its 2002 size of \$8.7 billion. NAND flash comprised 59 percent of the flash market and NOR flash 41 percent.¹⁹ The main products driving demand were flash memory cards used in cameras and mobile phones, USB drives, and flash-based MP3 players (see **Exhibits 5 – 10** for market data on the memory industry).

NAND flash was increasingly adopted in portable consumer electronic devices as a replacement for the hard disk drive. Although NAND flash continued to be more expensive per gigabyte than the hard disk drive, flash technology allowed electronics manufacturers to create smaller, lighter products, with low battery drain and high durability. Flash-based MP3 players and mobile phones were expected to stimulate future demand growth.

More importantly for Samsung, the company had succeeded in its goal of surpassing Toshiba to become the largest manufacturer of NAND flash memories in the world. Throughout the 1990s, Toshiba had been by far the market leader in flash technology, with over 50 percent market share. Through faster increases in bit density and the creation of new consumer products, such as the USB memory stick, Samsung was eventually able to overtake Toshiba in 2002 as the market leader, a position it retained in 2006. In 2006, Samsung had amassed a dominant 42 percent market share in NAND flash technology, compared with 19 percent for Toshiba.²⁰ The remarkable performance by which Samsung leap-frogged Toshiba involved a dedicated and focused effort that included all divisions within Samsung Semiconductor, including strategy, human resources, research and development, manufacturing, sales and marketing.

General Management & Strategy

The flash memory operations of Samsung were managed within the semiconductor division of Samsung Electronics. The semiconductor group was organized into five functional departments,

¹⁹ Gartner Dataquest, Samsung Electronics market research.

²⁰ Ibid, loc. cit.

including research, development, manufacturing, sales and marketing, and administration. The research group was responsible for the development of basic technologies and the development department applied those technologies to manufacturing.

Consistent with the operating philosophy of Samsung Group, Samsung semiconductor division believed that technological leadership was critical for its long-term operating success. As a result, the group invested heavily in research and development. Dr. Chang Gyu Hwang, President & CEO of the Semiconductor Business, believed that it was important that Samsung produce the first product within each new generation, because only then could the company drive the market to introduce new products:

When Toshiba was the leader, they led the industry in standardization. That's why in 1993 or 1994, we were asking Toshiba to work together to standardize applications or specifications of new products. By the early 2000s, when we became the leader, we initiated the use of flash in the mobile phone, MP3 players, and the USB drive.²¹

As the technological leader, Samsung could get products to market faster than competitors and enjoy first-mover profits. Samsung believed its position as the only provider of a total memory solution (including DRAM, SRAM, NAND flash, NOR flash, and multi-chip packages) gave it a further competitive edge with customers which used different memory components in a single device. Il-Ung Kim, Senior Vice President & General Manager in the Memory Division, explained:

By producing all different types of memory within Samsung, we have the advantage of being more efficient in terms of cost. In voice products and even digital cameras, customers are asking for DRAM and flash together in a single package. If you don't have DRAM in your factory, you have to acquire it from an outside supplier. Then you lose time in the end and you lose your cost benefit. So having different memory technologies inside the same company is becoming more important.²²

Broad strategic decisions, including new technology investments and demand creation, were made by the president of the semiconductor division with support from the various departments and the strategic planning group. The strategic planning group collected market share data and cost information, followed industry trends, conducted external surveys, and held discussions with internal management in constructing their analysis. Because of the risky nature of technology-based industries, there were many uncertainties in making strategic decisions. Samsung believed that managers needed strong technical knowledge in order to be confident in their decisions.

²¹ Quotations from Dr. Chang Gyu Hwang, President & CEO, Semiconductor Business, Samsung Electronics from case writer interviews July 13, 2006.

²² Quotations from I.U. Kim, Senior Vice President for Marketing, Memory Division, Samsung Electronics from case writer interviews July 13, 2006.

Human Resources & Training

Samsung also relied on an innovative approach to human resources for its success in technological development. Because the flash memory market was an industry of constant change, Samsung claimed that its engineers in the flash memory division had to work harder than employees in other areas. Samsung believed it had an advantage from the work style of Korean engineers who demonstrated the entrepreneurial and creative spirit of Western culture and the dedication to efficiency and operational excellence of Japanese culture. According to Dr. Hwang:

The Korean engineer is more likely to be internally motivated, very ready to shift goals, and more likely a mix of some Western culture and some Japanese culture. Japanese culture is more focused on killer technology, with a lot of people dedicated to one technology... But Korea is still sending many people to the U.S., smart and creative engineers, and when they return they are more likely to integrate technology. That's just their nature.

Bong Joo Lee, Senior Manager for Human Relations in the Memory Division, explained that the company's culture emphasized collaboration:

All employees can participate and discuss their opinions. This kind of atmosphere is very important, because we are at the leading edge of technology. We need to collaborate with the other areas. If people misunderstand or misjudge the direction of technology, it can be a great risk for our future.²³

To foster this culture, Samsung engineers were expected to exhibit the core values of the company. Mr. Lee described these values as: people first, excellence in work, adaptation to change, integrity, and co-prosperity (win-win among employees). Samsung believed that engineers who exhibited these core values would be more effective in collaborating in a group environment to translate technical knowledge into new products and advancements.

Samsung recruited engineers on university campuses. The company coordinated with university professors to co-develop curricula for students to apply advanced solid-state technology. The company also worked with professors on semiconductor process and design. Samsung monitored the performance of students working on such projects and recruited the most talented. The company also encouraged Samsung employees to identify and help recruit talented colleagues from around the world with whom they had previously worked in their PhD programs.

New employees were trained at the Samsung Group level, at Samsung Electronics, and at the Samsung semiconductor division, to learn about management philosophy, common culture and specific business practices. Successful engineers there were promoted to management and given additional training. Although most managers at Samsung were promoted from within, as the company grew it increasingly went outside to fill higher-level positions. Employees were

²³ Quotations from Bong Joo Lee, Senior Manager for Human Resources, Memory Division, Samsung Electronics from case writer interviews July 13, 2006.

remunerated with both individual performance bonuses and division-level profit-sharing, based on achieved results and living the company's core values.

Research & Development

To maintain technological leadership, Samsung insisted on hiring very talented engineers who fitted into the company culture. In the early days of the flash program, engineers with DRAM and EEPROM experience were assigned to the creation of the new technology. The three key tasks that they were assigned to were chip design, manufacturing line set up, and mass production process. They behaved as if the survival of the very company were at stake, working seven days a week and living in housing on the Samsung campus. Engineers were kept excited by the idea of the new technology they were creating, as well as the challenge of taking on the technological leader in the industry. Because only broad specifications for flash technology were available (but not detailed designs), the engineers made many mistakes. However, the research and development managers encouraged a collaborative atmosphere where mistakes could be discussed and solutions found. Dr. Suh described the culture at the time:

We did a design and there were problems. How to define the problem and how to repair the problem were very important... Everyone had an open mind and we taught each other, young people, old people.

Senior engineers and managers worked together to make major decisions. A Flash Steering Committee was established, headed by Dr. Hwang, which held monthly meeting to review progress and make strategic decisions and approve investments. The steering committee oversaw the work of the NAND Flash Task Force Team, which was responsible for working level issues. The Task Force Team was comprised of managers from design, manufacturing, quality assurance, marketing, and product planning, and had a leader assigned to each specific area to resolve all outstanding issues. Even though the task force reported to the steering committee, it operated with a high level of autonomy. The task force held weekly status meetings and assigned in-charge point persons to check progress and make sure that work was carried out. The use of a cross-functional task force of engineers allowed Samsung to resolve issues rapidly by addressing them simultaneously rather than one by one. It also allowed team members with different technical specialties to share knowledge about all steps in the production cycle, from design to manufacturing. It was an approach that the company had employed several years before when constructing its first DRAM fabrication plant.

The company sought to reinforce the learning and progress made by the task force through internal technical seminars, covering such topics as flash memory manufacturing, cleaning processes, how measurement equipment worked, and trends in consumer products. Seminars helped team members to have a deep understanding of important steps in the production process that were outside of their specific domain. They also allowed engineers to gather feedback on their work and hear alternative viewpoints from colleagues. Over time, the expertise of the entire research and development team improved and by the late 1990s, the technical knowledge had been widely institutionalized. In recognition of this, Samsung's leaders reduced the work week to six days.

After the product design team completed their design of a new product, they were still in charge of working with the manufacturing team to develop processes for mass production. The company believed that continued involvement from the design team that had intimate knowledge of the product would reduce lead time from design to mass production and increase manufacturing efficiency more rapidly than if sole responsibility were transferred to the manufacturing team. The research group also sought a technological advantage in addition to a manufacturing advantage by developing technologies two to three generations ahead. According to Dr. Hwang, researching future generations of technology allowed Samsung to leapfrog its competitors:

All the technology development and insight came from preparing not only the next generation but two or three generations ahead. We developed flash memory using the same techniques we had used in DRAM development... We always set up two generations ahead in R&D. So, when 4 megabit was in the market, we set up plans for 16 megabit and 64 megabit. That was the process we used to catch up in technology when, at the time, we were behind Toshiba.

Applying this approach to the flash memory market in 2005 while 4 gigabit technology was widely in use, Samsung already had 8 gigabit technology in design and planned for mass production of 16 gigabit technology by the end of 2006, demonstrating their belief in an extraordinary rate of technological change (see **Exhibit 11** for Samsung's technological improvement of NAND flash).

The research group also focused on developing technologies tailored to specific devices. Samsung assigned multi-functional planning teams as part of the Task Force Team to determine how flash could be used in different products sold by key customers. For example, in 2001, Samsung created a product team that worked exclusively on developing graphic and memory technology for the Microsoft Xbox. By working with Microsoft from the beginning, Samsung was able to understand the technological requirements and develop technologies to meet those requirements, thereby securing a large advantage over competitive suppliers. Similarly, Samsung established joint research and development teams with other Samsung Electronics divisions in various fields, such as digital TV and LCD monitors, thereby strengthening the competitiveness of Samsung's memory products.

The research group also invested in a wide portfolio of alternative technologies, including those which might one day replace NAND flash. In 2006, technology was approaching the physical limit to the width of lines that would fit on a memory chip. Samsung was exploring 3 dimensional technologies and new materials that could provide the next level of breakthrough. Although the most advanced category of semiconductor technology was the microprocessor, Samsung believed it could not easily enter that market, because the technology required experienced software engineers, located mostly in the United States. An additional barrier was the close working relationship between Intel and Microsoft, who jointly determined the next generation system technology. The policy of working one or two generations of technology ahead, coupled with the search for future replacement technologies, also had the motivational value of generating excitement and loyalty amongst the Samsung engineers.

Manufacturing

Samsung operated 11 manufacturing lines in three fabrication sites for the production of DRAM, SRAM, flash and other memory chips. Samsung was unique among semiconductor manufacturers in that all of its fabrication plants were located near division headquarters, south of Seoul, and were company-owned. Most competitors ran production in diverse locations: Taiwan, Japan or the United States, and many of them engaged in contract manufacture for other customers. The financial consequences of Samsung's preference for owning its own fabs were substantial: in 2006, a new fabrication plant required an investment of \$4 to \$5 billion, which had to be financed.

Despite the investment requirements, Samsung gained additional advantages in the flash market by being the market leader in DRAM with its own production capacity. Flash memory could be manufactured using DRAM production lines with only small changes in equipment, because the processes for the two technologies were identical (even though the product architectures differed). As a result, investment to manufacture flash memory using a converted DRAM line required only about 20 percent of the cost of constructing an entirely new flash line. In addition, the time to conversion was only two to three months, which was very short compared with the one to two year time to construct a new plant. With the convertibility between DRAM and flash memory lines, Samsung could increase capacity rapidly to meet growing demand and at low cost relative to competitors. The company could also shift the lines between the two technologies to optimize production mix as demand changed. By comparison, Toshiba had sold its DRAM lines to Micron in 2001, which prevented the company from increasing NAND flash manufacturing capacity at the pace necessary to maintain market share (see **Exhibit 12**).

From a technological standpoint, the initial production of each new generation was not as efficient as the previous generation, due to the "learning curve" effect. All of the chips produced on a wafer were tested to ensure performance and the proportion of chips which performed correctly per wafer was defined as the yield. Defective chips wasted production capacity and increased costs. The more quickly a company could improve its yield on each new generation, the sooner it could reach profitability. The size of the wafer (which determined the number of chips per wafer) and the yield were key determinants of cost, and one of the means of improvement in technology was to increase the wafer diameter. In the early days, Samsung manufactured NAND flash on 8 inch wafers. In 2003, Samsung invested in the capacity to produce 12 inch wafers, a decisive but necessary step to maintaining its market growth.

The flash memory industry was highly cyclical as a result of the successive generations of technology. Every nine to 18 months, the density on a single chip would double. When a new chip was introduced to the market, the price per unit was high because the total industry volume was low and the yields from wafer fabrication were also low. As competitors copied the new generation, increasing volume and improving yield, the manufacturers' cost and selling price would fall. Eventually, the new generation would become a commodity and approach the price of the preceding generation. As a result of this cycle, companies that could get to market first with a new generation would enjoy the high prices that came with initially being the sole supplier. They also benefited over the cycle from being first down the learning curve. Being first with a new generation of product and increasing plant utilization rapidly were critical to ensuring

an adequate return on capital. Profitability enabled the company to invest in the next generation of technology, creating a virtuous circle.

Samsung also increased manufacturing efficiency by integrating production and planning into its customers' supply chain management systems. Samsung used such systems to improve every step of production, from demand forecasting to managing accounts receivables. For example, the company analyzed usage data to create weekly forecasts of customer demand. Samsung thereby was able to reduce cycle times and inventory costs.

The dramatic impact of the learning curve and supply chain management could be seen in Samsung's expectations for the 8 gigabit flash memory. In July 2006, Samsung was producing 8 gigabit flash technology at a 15 percent yield. It was able to produce 500,000 units at an average cost of \$25. It expected that by September 2006, two months later, it could improve the yield to 80 percent and produce 15 million units per year at an average cost of \$8.

Marketing & Sales

Samsung's marketing and sales departments maintained close relations with both internal customers (from Samsung Electronics) and external customers. The company claimed that external customers were confident that Samsung Semiconductor Division would not share information with other divisions of Samsung Electronics, with which they competed. In 2006, Nokia was the largest customer of Samsung flash memory products. Other major customers included Sony, Apple, Dell, Hewlett-Packard, and IBM. Samsung Semiconductor had to compete against outside suppliers such as Toshiba when it came to supplying internal customers at Samsung Electronics. This market discipline ensured that Samsung Semiconductor remained competitive in price and that all Samsung Electronics divisions competed efficiently.

The marketing department was organized by product and divided into two main groups, DRAM and non-DRAM. The DRAM group included an EDP (electronic data processing) DRAM group which supplied PC manufacturers, a Mobile Memory group, which supplied cell phone and mobile device manufacturers, and a Graphics group, which marketed to game console manufacturers. The non-DRAM group was responsible for NAND flash, NOR flash, and MCP (multi-chip packages).

The sales department was organized in two groups: by geographic area with teams dedicated to North America and Europe, Japan and China, Korea; and centrally with respect to multinational companies. The marketing representatives were responsible for the technological roadmap and product offerings, while the sales representatives took care of pricing and negotiations with customers.

Maintaining Market Share in a Fast Growing Market

Because of the high fixed costs, profitability depended on the marketing department in the Flash Memory Division balancing supply and demand. The marketing department regularly forecast demand 12 weeks forward on a rolling basis, while at the corporate level the company made forecasts of demand three years ahead. Forecasts were based on customer demand data provided by the sales department, and the marketing department used the forecast to adjust production

plans. When the forecast predicted an excess in industry supply, there was great pressure on the marketing department to find new consumer applications to stimulate demand.

For example, in September 2004, Samsung forecast an oversupply of NAND flash for 2005. At the time, Apple Computer had a dominant position in the MP3 market with its new iPod music player, which used hard disk drive for its memory. Samsung realized that if it could convince Apple to create an iPod based on flash memory, it could change the balance of supply and demand for the entire flash industry. According to I.U. Kim, Samsung approached Apple CEO Steve Jobs about introducing a flash-based iPod:

Apple was doing well in the MP3 market, which was based on the hard disk drive rather than NAND flash. We tried to persuade them to change in September 2004. The first time they refused. They were doing well in the market using a hard disk drive, but one thing they were looking at was how to expand the total market size... Later on they counter-offered us: if we could meet their target price for a certain density, they would change from hard disk drive to NAND flash in certain segments of their MP3 markets.

Apple proposed that if Samsung could bring down the cost of 4 gigabytes from \$250 to \$100 within a year, it would create an iPod based on flash technology. At the time, Samsung was developing the next generation of flash technology, which, if high yields could be reached, might allow it to meet these aggressive price targets. According to Kim:

We realized that if we could develop our 4 gigabit technology on time, we would be able to supply them without making any loss. And, given their power in this market, we could create a whole new market that would change the future dynamic of demand and supply for NAND flash memories.

Samsung recognized, however, that from a strategic standpoint it would be handing competitors a market advantage, in that Samsung would have to dedicate 30 percent of its flash production capacity to supply 4 gigabytes at \$100, while the market price for other consumer products would remain higher. Kim explained:

In terms of the technology, the risk was relatively small. But in terms of the profit, that was a very difficult decision because I had to allocate capacity at such a low price to one customer. When the market rebounded from oversupply to shortage, only 70 percent of our production capacity would benefit from a higher price, because we had to allocate 30 percent of our capacity to Apple at the agreed to price. But competitors would enjoy 100 percent of their capacity at a higher price.

In the end, Samsung agreed. Apple produced the iPod nano using flash technology, and Samsung succeeded both in finding a new demand for its technology and in defining a new consumer product segment.

The Challenges of Success

In 2006, Samsung believed that the future for flash technology remained bright because consumer products based on flash technology could be designed to be lighter, sleeker, and more durable and with a longer battery life than those with hard disk drives. It expected that in the next few years, demand for cell phones with memory slots would provide a large new source of demand. Memory slots would allow substantially more information to be stored on a cell phone, and as a result increase the device's functionality for downloading and listening to music and video, for playing video games, and for installing polyphonic ring tones and animated screen savers. In 2006, the expected market for cell phones was 900 million units globally, 100 million of which would likely have memory slots. In five years, the market for cell phones was forecast to be 1.5 billion, of which 50 percent would have memory slots – a potentially huge opportunity.

Samsung also expected that by the end of 2008 the laptop PC market would finally begin replacing hard disk drive memory with flash memory. While hard disk drive manufacturers were expected to produce PCs with 100 to 200 gigabytes of storage, most industry surveys indicated that PC owners typically required only 30 gigabytes or less. Through continued improvements in chip density, Samsung expected to be able to produce 64 gigabit density chips within the next few years and combine four 64 gigabit chips into a single flash memory to create 32 gigabytes of storage at a very competitive price. From that point, Samsung hoped to gain 10 percent of the 100 million unit laptop market.

Convergence of handheld devices, including cell phones, MP3 players, and digital cameras, into a single device would also drive demand. According to Dongkun Lee, Senior Manager for Strategic Planning in the Memory Division:

The trend in the NAND flash market is from iPod nano to cell phones. So the cell phone market is going to be much larger than the iPod nano, eventually, because the MP3 player functions can be converged into the cell phone... All the functions and features you can imagine will be converging into one single smart device.²⁴

These devices would require multiple chips in each unit, a combination of DRAM for buffering, NAND flash for writing and NOR flash for reading. Demand for video capabilities would ensure that consumers required an increasing amount of storage capacity in their handheld devices. Samsung felt it was ideally situated to meet these expanding requirements for years to come.

The flash memory market, however, was expanding much faster than the rate at which Samsung could add production capacity. Kim explained the risk that this expansion threatened to Samsung's market share position:

The market is too big. I don't think we can invest fast enough to meet all the demand... Adding just one single fab costs us \$4 billion to \$5 billion. And given our current cash flow it is impossible to add two fabs per year. For us, the market

²⁴ Quotations from Dongkun Lee, Senior Manager for Strategic Planning, Memory Division, Samsung Electronics from case writer interviews July 13, 2006.

share we enjoyed last year, which was over 50 percent, is too high to maintain. The market is expanding much faster than we can add fabs.

Kim pondered the difficult decision facing Samsung Electronics: how to maintain its leading market share in a business that was on the verge of explosive growth, but which required enormous investments from a corporation which had many other demands on its capital.

Should Samsung try to hold its market share? With each fabrication plant costing \$4 to \$5 billion, how much investment should Samsung make in new capacity? What investment would be appropriate, given the portfolio philosophy of the Samsung Group? Should Samsung consider outsourcing production to fabrication plants it did not own? What implications would that have for the company's strategy?

The larger question was Samsung's technological leadership and how likely it was that Samsung could retain its position. Would Samsung engineers, now the technological leaders, maintain their motivation to stay at the cutting edge? What could the company do to maintain its technological leadership?

Exhibit 1 Samsung Group: Company Profiles (2005)

Company	Description	2005 Revenue (\$ millions)
Samsung Electronics Co.	Semiconductor, telecommunication, and appliances	\$79,600
Samsung Life Insurance Co.	Life insurance	\$22,750
Samsung Corp.	Construction, international trade, and retail	\$9,700
Samsung Fire & Marine Insurance Co.	Property & casualty insurance	\$8,110
Samsung SDI Co.	Materials and components for display devices	\$7,880
Samsung Heavy Industries Co.	Shipbuilding, engineering and construction	\$5,850
Cheil Industries	Textiles and fashion	\$2,600
Samsung Total Petrochemicals Co.	Chemical and petrochemical manufacturing	\$2,500
Samsung Techwin Co.	Precision machinery, aircraft engine, and cameras	\$2,400
Samsung Card Co.	Credit cards, consumer and commercial lending	\$2,370
Samsung Electro-Mechanics Co.	Components for electronic devices	\$2,200
Samsung SDS Co.	IT consulting and services	\$1,890
Samsung Corning Precision Glass	LCD and glass for display devices	\$1,700
Samsung Securities Co.	Investment banking and wealth management	\$1,440
Samsung Petrochemical Co.	Petrochemicals	\$1,400
Samsung Everland	Resort development and management	\$1,380
Samsung Engineering Co.	Construction management	\$1,010
Samsung Corning Co.	Glass, coatings, other materials for display devices	\$823
Samsung Fine Chemicals Co.	Fine chemicals and electronic chemical materials	\$781
S1 Corp.	Security systems	\$626
Cheil Communications	Advertising	\$537
Samsung Networks	Communication infrastructure services	\$465
Shilla Hotel & Resorts	Hotels, shops, restaurants, and hospitality consulting	\$430
Samsung BP Chemical Co.	Acetic acid production	\$295
Samsung Investment Trust Mgt. Co.	Investment management	\$66
Samsung Venture Investment Corp.	Venture capital	\$9
Samsung Advanced Inst. of Technology	Basic research, seed technology and patent development	-
Samsung Economic Research Institute	Economic research	-
Samsung Foundation of Culture	Museums and cultural activities	-
Samsung Lions	Professional baseball team	-
Samsung Medical Center	Hospitals and bioscience research	-
Samsung Welfare Foundation	Childcare, social welfare, and societal development	-

Source: Samsung Group, "2005 Annual Report," 2006, <http://www.samsung.com/Aboutsamsung/samsunggroup/AnnualReport/AnnualReport/index.htm>, (August 31, 2006).

Exhibit 2

Samsung Electronics: Product Information, by Business Unit (2006)

Semiconductor

Memory	Market leader in DRAM, SRAM, flash, and multi-chip packages.
System LSI	System logic and processors for use in digital and wireless technologies.
Storage	Storage devices including hard disk drives and optical drives.

Telecommunication

Mobile Phones	Number 3 global market share in mobile phones; includes satellite phones, camera phones, with focus on mid-high end segment.
Wireless Technology	Communications standards for mobile phones, including CDMA (a multiple access scheme) and Mobile WiMAX (a high speed wireless internet format).
Network Equipment	Fiber optics, broadband, home network, and office network solutions.

Digital Media

Television	Number 1 global market share in color televisions.
Audio and Video	MP3 players, home audio systems, camcorders, and set top boxes. Number 1 global market share in DVD/VCR machines.
Computer	Thin and light model laptops. Number 1 global market share in computer monitors.
Printer	Laser printers.

Digital Appliance

Appliances	Refrigerators, air conditioners, washing machines, microwave ovens, and vacuum cleaners, with a focus on next-generation, environmentally friendly, and energy efficient units.
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Liquid Crystal Display (LCD)

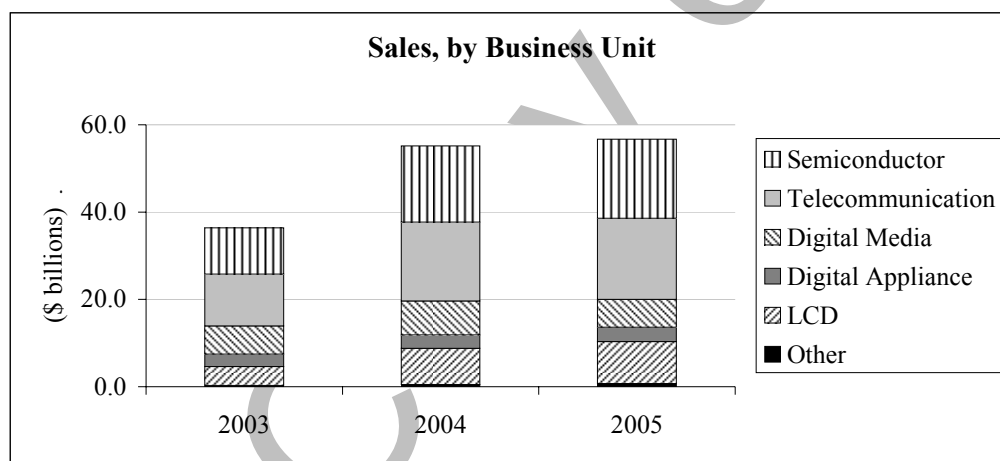
Monitors	Computer monitors for desktop and laptop PCs.
Televisions	TFT (thin film transistor) LCDs for televisions from 15 to 82 inches.
Mobile Phones	Brilliant display to enhance multimedia functionality in mobile phones.

Source: Samsung Electronics.

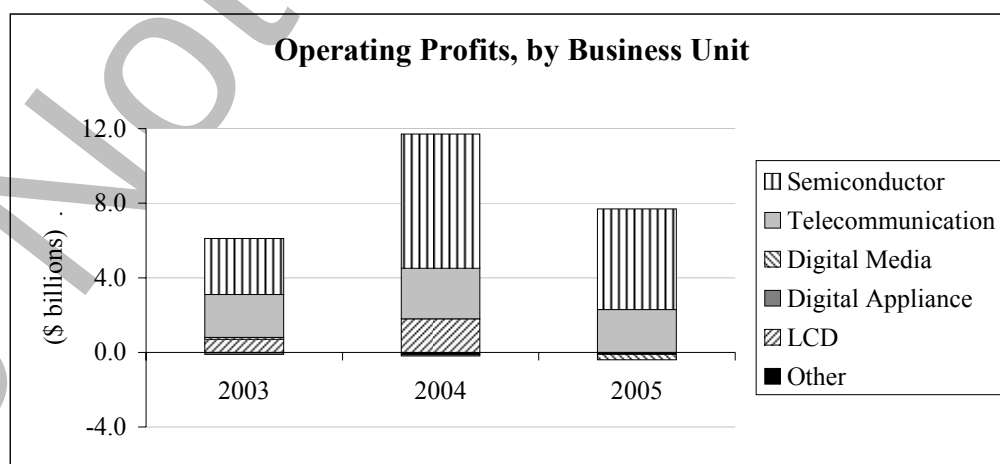
Exhibit 3
Samsung Electronics: Selected Financial Information (2001 – 2005)

(\$ billions)	2001	2002	2003	2004	2005
Consolidated Revenues	\$35.0	\$48.7	\$54.1	\$78.5	\$79.6
Parent Revenues	\$24.4	\$33.3	\$36.4	\$55.2	\$56.7
Net Income	\$2.2	\$5.9	\$5.0	\$10.3	\$7.5
Capital Expenditures	\$3.1	\$3.5	\$5.6	\$7.4	\$9.9
Employees	67,000	78,000	88,000	136,000	136,000

Source: Samsung Electronics. Consolidated revenues include revenues of Samsung Electronics and its controlled subsidiaries, which include majority-owned entities and entities in which Samsung Electronics owns more than 30 percent of the total outstanding voting stock and is the largest shareholder.



Source: Samsung Electronics. Sales figures at the parent level.



Source: Samsung Electronics. Operating profits at the parent level.

Exhibit 4

Definitions of Semiconductor Technology

Bit – A “binary digit,” the basic building block of computer communications. A bit takes on the value of 0 or 1, representing the two electrical states: on and off (charge or no charge; positive or negative).

Byte – A group of bits (usually eight).

Boolean logic – A set of rules that govern true-false logic functions. Developed by English mathematician George Boole in the mid-1800s, Boolean logic is based on the primary operations of “and,” “or,” and “not.”

Chip – A rectangular piece of silicon on which a large amount of circuitry is implanted; also known as a die or an integrated circuit or semiconductor.

Wafer – A thin circular silicon disk, usually 0.6 millimeters (mm) thick and 150 mm to 300 mm in diameter, which forms the substrate of an integrated circuit.

Yield – The number of acceptable quality chips as a percentage of the total number of chips available on a wafer.

ROM – Read-only memory.

RAM – Random access memory. Data in any part of the memory can be accessed at any time and does not require the sequential reading of data from a specified starting place.

Volatile Memory – A memory device that does not retain stored information when power is interrupted.

Non-Volatile Memory – A memory device that retains stored information when power is interrupted.

DRAM – Dynamic random access memory. “Dynamic” means that the device’s memory cells need to be periodically recharged. These semiconductor devices, which store digital information in the form of bits, provide high-speed data storage and retrieval. As high density, low-cost-per-bit memory components, DRAMs are the most widely used semiconductor devices in PC systems.

SRAM – Static random access memory. A semiconductor memory that requires no constant refreshing or recharging; it stores information as long as power is applied to the computer. SRAMs are much faster but more expensive than DRAMs.

EPROM/EEPROM – Erasable programmable read-only memory and electrically erasable programmable read-only memory. Both are non-volatile memory devices that retain stored information when electrical power is interrupted. These are predecessor technologies which were largely replaced by flash memory.

NOR Flash – A type of nonvolatile memory capable of fast data reading. NOR flash is commonly used to store executable code, for instance, in mobile phones and personal digital assistants (PDAs).

NAND Flash – A type of non-volatile memory capable of fast data writing but slower in data reading than NOR flash. NAND flash has become popular for products where large data storage or fast writing capability is needed, such as MP3 music players and digital cameras.

Multi-chip packages – A process where more than one semiconductor technology is combined on a single chip.

Source: Standard & Poor’s Industry Survey: Semiconductors, November 16, 2006.

Exhibit 5
Samsung Electronics: Market Share Information (1985 – 2005)

Global Semiconductor Industry

(\$ millions)	1985	1990	1995	2000	2005
Revenue, Samsung Electronics	\$95	\$1,315	\$8,332	\$10,585	\$18,347
Revenue, Global Industry	\$24,205	\$54,545	\$151,262	\$226,228	\$234,692
Samsung Market Share	0.4%	2.4%	5.5%	4.7%	7.8%
Samsung Rank	42	13	6	4	2

Source: Gartner Dataquest, Samsung Electronics.

Global Memory Industry

(\$ millions)	1985	1990	1995	2000	2005
Revenue, Samsung Electronics	\$21	\$971	\$7,498	\$8,749	\$15,437
Revenue, Global Industry	\$3,805	\$12,128	\$55,287	\$54,374	\$49,753
Samsung Market Share	0.6%	8.0%	13.6%	16.1%	31.0%
Samsung Rank	26	4	1	1	1

Source: Gartner Dataquest, Samsung Electronics.

Exhibit 6
Global Semiconductor Industry: Top 20 Companies (2004, 2005)

(\$ millions)	2004	2005	Market Share 2005
1. Intel	\$30,730	\$34,590	15%
2. Samsung Electronics	\$16,276	\$18,347	8%
3. Texas Instruments	\$9,170	\$10,119	4%
4. Toshiba	\$8,538	\$8,984	4%
5. ST Microelectronics	\$8,691	\$8,821	4%
6. Renesas Technology	\$9,001	\$8,291	4%
7. Infineon Technologies	\$8,945	\$8,205	3%
8. Philips Electronics	\$5,689	\$5,959	3%
9. Hynix Semiconductor	\$4,648	\$5,723	2%
10. NEC Electronics	\$6,438	\$5,657	2%
11. Freescale Semiconductor	\$5,519	\$5,599	2%
12. Micron Technology	\$4,557	\$4,620	2%
13. Sony	\$3,731	\$4,304	2%
14. Advanced Micro Devices	\$5,001	\$3,936	2%
15. Matsushita	\$3,845	\$3,779	2%
16. Sharp	\$3,908	\$3,569	2%
17. Qualcomm	\$3,211	\$3,457	1%
18. Rohm	\$2,904	\$2,919	1%
19. IBM Microelectronics	\$2,426	\$2,855	1%
20. Broadcom	\$,2401	\$2,671	1%

Source: Gartner Dataquest, Samsung Electronics.

Exhibit 7
Global Memory Industry: Revenue by Technology Segments (2004, 2005)

(\$ millions)	2004	2005	1-Year Change
Memory	\$48,067	\$49,753	4%
Dynamic RAM	\$26,317	\$25,206	-4%
Static RAM	\$4,120	\$3,472	-16%
Non-Volatile Memory	\$17,193	\$20,676	20%
EPROM	\$429	\$370	-14%
EEPROM	\$969	\$922	-5%
Flash Memory	\$15,441	\$19,088	24%
NOR Flash	\$8,434	\$7,131	-15%
NAND Flash	\$7,007	\$11,957	71%
Mask ROM	\$354	\$296	-16%
Other Memory	\$437	\$399	-9%

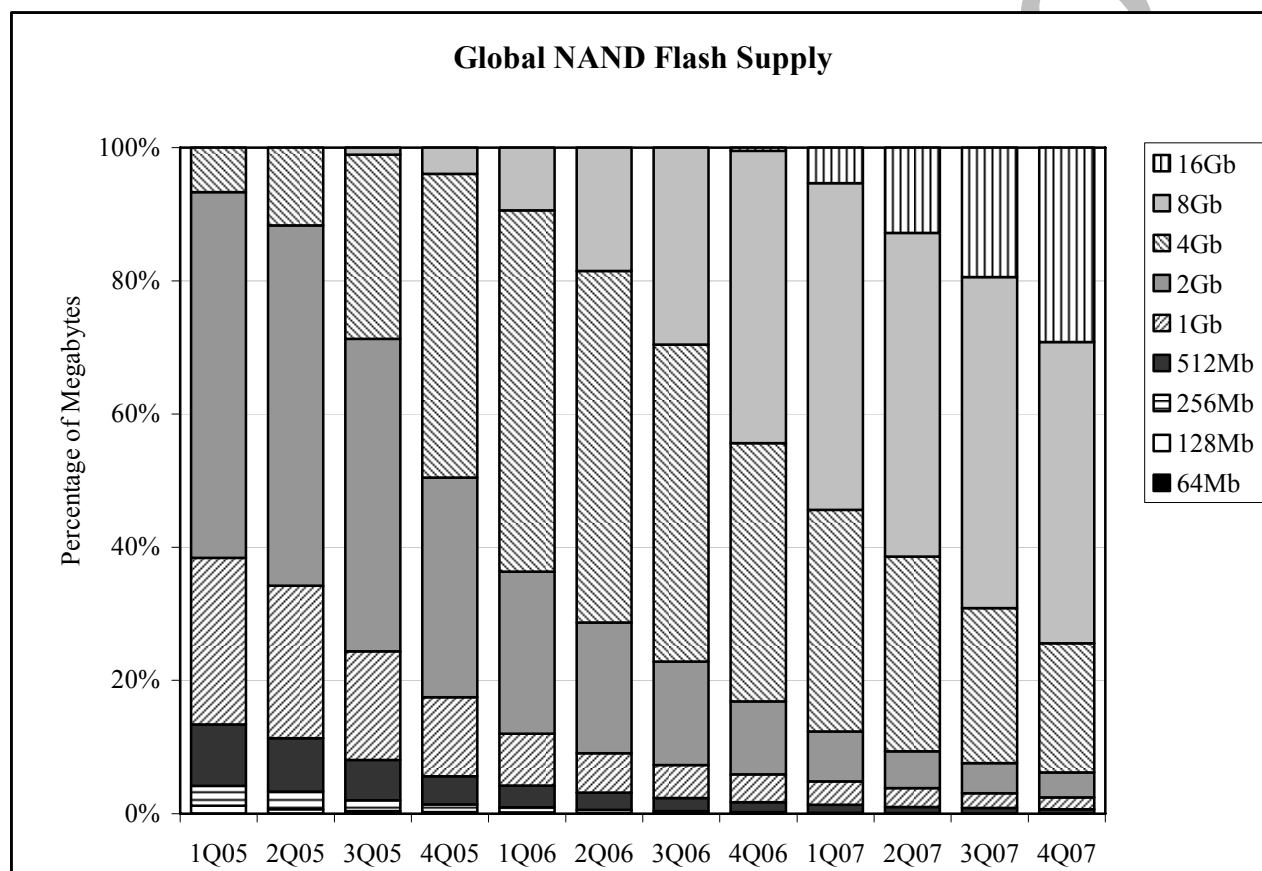
Source: Gartner Dataquest, Samsung Electronics.

Exhibit 8
Systems Using NAND Flash Memory: Actual and Forecast, by Product (2004 – 2007)

(thousands of systems)	2004	2005	2006	2007
Digital Audio Players (Flash)	26,375	107,838	161,139	207,721
Digital Camcorder	11,900	13,000	13,800	14,500
Digital Cellular Handsets, 2G	138,359	143,840	116,054	65,429
Digital Cellular Handsets, 2.5G	377,361	490,214	574,505	628,934
Digital Cellular Handsets, 3G	158,146	177,796	267,497	388,284
Digital Set Top Box — IP/Other	889	2,760	4,536	6,621
Digital Still Camera	61,250	71,650	78,500	83,200
Disk Drive — RDD	300,336	380,273	445,285	492,290
GPS Navigation Systems	10,880	12,735	14,950	17,900
Handheld Computers	12,033	12,952	14,125	15,109
Inkjet Printers	50,388	50,328	48,166	46,375
Monochrome & Color Printers	16,193	19,659	20,888	21,237
Multifunction Printers	34,512	45,520	52,490	58,734
Other Automotive	60,792	62,601	64,505	66,073
PC —Notebook (Home)	17,241	24,553	31,519	38,785
PC — Notebook (Professional)	29,938	38,918	48,294	57,791
PC —Desktop (Home)	17,241	51,385	55,276	56,690
PC — Desktop (Professional)	29,938	96,731	97,130	100,599
RS3 — Flash Cards	225,867	375,050	502,625	566,725
RS3 — USB Flash Drives	51,656	85,171	115,705	142,250
Smart Cards	1,691,600	2,227,840	2,706,000	3,209,600
Video Game Console	22,830	29,022	27,704	35,989
Video Game Handheld	21,944	34,976	35,552	27,866

Source: Gartner Dataquest, Samsung Electronics (Forecast as of May 2006).

Exhibit 9
Density of NAND Flash Memory: Actual and Forecast, by Product (2005 – 2007)



Source: Gartner Dataquest, Samsung Electronics (Forecast as of May 2006).

Exhibit 10
Shipments of NAND Flash Memory: Actual and Forecast, by Company (2004 – 2007)

(millions of units)	2004	2005	2006	2007
Hynix Semiconductor	-	255.0	412.7	541.6
Infineon Technologies	5.9	31.5	34.0	57.7
Intel	-	-	47.0	119.3
M-Systems	9.1	15.9	23.0	26.1
Micron Technology	0.2	21.3	47.0	119.3
Powerchip Semiconductor	-	-	14.6	43.0
Renesas Technology	35.9	65.9	79.3	84.8
SanDisk	83.9	102.2	138.6	205.6
Samsung Electronics	363.8	543.2	758.8	1,016.0
SMIC	-	-	1.1	7.0
Spansion	-	-	4.9	36.4
STMicroelectronics	4.4	40.4	71.7	65.6
Toshiba	170.6	207.5	281.4	417.4

Source: Gartner Dataquest, Samsung Electronics (Forecast as of May 2006).

Exhibit 11
Samsung Electronics: Mass Production of NAND Flash

Density	Date Mass Produced	Line Width
64 Mb	May 1995	400 nm
128 Mb	Sep 1998	270 nm
256 Mb	Jun 2000	220 nm
512 Mb	Jun 2001	150 nm
1 Gb	Aug 2002	120 nm
2 Gb	Feb 2004	90 nm
4 Gb	May 2005	73 nm
8 Gb	In process	51 nm

Source: Samsung Electronics.

Exhibit 12
Samsung and Toshiba: NAND Flash Memory Revenue and Market Share (2000 – 2006)

(\$ millions)		2000	2001	2002	2003	2004	2005	2006
Worldwide	Sales	\$1,563	\$1,378	\$2,364	\$4,131	\$7,007	\$11,957	\$13,650
	Growth		-12%	72%	75%	70%	71%	14%
	Sales	\$411	\$374	\$1,050	\$2,003	\$3,750	\$6,059	\$5,670
Samsung	Growth		-9%	181%	91%	87%	62%	-6%
	Share	26%	27%	44%	49%	54%	51%	42%
	Sales	\$704	\$432	\$626	\$1,160	\$1,780	\$2,307	\$2,636
Toshiba	Growth		-39%	45%	85%	53%	30%	14%
	Share	45%	31%	27%	28%	25%	19%	19%

Source: Gartner Dataquest, Samsung Electronics.