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Hewlett-Packard: The Flight of the Kittyhawk (A)

In 1903, on a windy beach in Kitty Hawk, North Carolina, Orville and Wilbur Wright demonstrated that sustained flight was possible. Though their plane only flew 120 feet on the first attempt, they flew farther and higher on each successive trial. The two brothers stood at the threshold of a new era in transportation.

In June of 1992, Hewlett-Packard (HP) introduced the smallest hard disk drive in the world, named the Kittyhawk. The drive's disks were 1.3 inches in diameter; the unit was not much larger than two postage stamps (see **Exhibit 1** for a picture of the Kittyhawk). The first version of the Kittyhawk supplied 20 megabytes of storage and had unique componentry enabling the drive to withstand a three-foot drop without any data loss. The possible applications of the drive in the mobile computing market seemed endless, and the team at HP responsible for launching the Kittyhawk eagerly anticipated the takeoff of their newest innovation. However, now, in June 1994, after two years of effort, Kittyhawk sales had failed to meet the team's targets, and Rick Seymour, the Kittyhawk project leader, was struggling with whether to refocus the team's effort along one of three possible paths his staff had developed or to recommend to his superiors that the project be abandoned and the team disbanded.

Rigid Disk Drives

Rigid disk drives (commonly called "hard drives") were magnetic information storage and retrieval devices used with computers. The first rigid disk drive, invented in 1956 by engineers in IBM's San Jose, California laboratories, was the size of two large refrigerators placed side by side. It could store five megabytes (MB) of information. The technological progress since that time was remarkable. Drives wrote and read information in the same sort of binary code that computers used. Most disk drives comprised a read-write head mounted at the end of an arm that swung over the surface of a rotating disk in much the same way that a phonograph needle and arm reached over a record; disks, which were aluminum or glass platters coated with magnetic material; at least two electrical motors—a spin motor that drove the rotation of the disks and an actuator motor that moved the head to the desired position over the disk; and a variety of electronic circuits that controlled the drive's operation and its interface with the computer.

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The read-write head was a tiny electromagnet whose polarity changed whenever the direction of the electrical current running through it changed. Data were written onto disks by sending electrical pulses through the head's electromagnet to create minute magnetic flux fields that oriented the magnetic polarity of particles (the domain) on the disk surface immediately beneath the head. With domains being given either positive or negative polarity in this way, information could be stored in binary code. Data could be retrieved from the disk's surface by reversing this process. A disk drive's architecture was categorized by the size of the disk's diameter (i.e., a 3.5-inch disk drive).

The Disk Memory Storage Division

From Hewlett-Packard's earliest beginnings as an electronic instruments company to its domination of the printer industry, the HP culture deeply valued technical innovation as a key to success. HP employed a management-by-objective (MBO) process to focus its businesses on financial goals and its people on the potential paths of innovation and strategy to achieve such goals. HP favored a decentralized organizational structure so as to allow its businesses freedom of decision making and movement.

HP had four major business organizations—Test & Measurement, Computer Systems, Measurement Systems, and Computer Products. Of these four, the Computer Products Organization consisted of the company's laser printer, ink-jet printer, personal computer, and mass storage product groups. The Mass Storage Product Group developed and managed HP's storage technologies (see **Exhibit 2** for the Mass Storage Group's organization chart). The Disk Memory Division (DMD), which was responsible for developing and launching the Kittyhawk and other disk-drive models, resided within the Mass Storage Group.

Based in Boise, Idaho, DMD had disk-drive sales in 1992 of $519 million, approximately 80% of which was derived from original equipment manufacturer (OEM) orders and the rest from HP's internal computer businesses.[1] HP's corporate net revenue was at $16 billion. (See **Exhibit 3** for a 10-year comparison of HP corporate revenues versus its disk-drive revenues.) At the same time, the industry leaders, IBM and Seagate Technology, had disk-drive sales of $4 billion and $3 billion, respectively.[2]

Although small in comparison to some of the other disk-drive manufacturers, DMD had a profitable position within the market. It concentrated on high-performance products within the 5.25- and 3.5-inch architectures that supplied healthy profit margins to the division. Consequently, HP's product line offered a substantially higher capacity in megabytes than the industry norm (see **Exhibit 4**). For many of DMD's research and development (R&D) engineers, the most sought-after projects were the ones that developed the next-generation drives that furnished ever-higher capacities and faster access times. Concentrating on the high-end engineering workstation and network server markets, DMD had been among the first in the industry to introduce one and two gigabyte drives.[3] These disk drives were extremely successful in the marketplace.

[1] 1993 Disk/Trend report.

[2] Ibid.

[3] One gigabyte is equivalent to 1,000 megabytes.

The Kittyhawk

Genesis of the Idea

Bruce Spenner, the general manager of the Disk Memory Division, came to HP in 1978 from teaching electrical engineering at Washington University in St. Louis. A few years after joining HP Labs, he was part of the company's top-priority project to implement reduced instruction set computing (RISC) architecture into HP's minicomputers and workstations. While other computer companies did not fully believe the benefits of RISC and balked in implementation, HP's full commitment to the architecture made it the leader in Unix computing. Described by employees as not the typical "meet the numbers" manager, Spenner was widely viewed as a visionary and risk taker. At HP Labs, his responsibilities soon expanded into overseeing a software laboratory that produced major new breakthroughs. Dick Hackborn, who had built HP's highly successful printer business and was now executive vice president in charge of the company's Computer Products Organization, liked Spenner's concept-driven thinking. In 1990, Ray Smelek, general manager of the Mass Storage Product Group, promoted Spenner to general manager of the Disk Memory Division.

DMD was an anomaly within HP. It had been selling drives externally to OEMs since 1984 and, though profitable, was still a niche player from a disk-drive industry perspective. In contrast, HP as a whole took pride in its ability to be a market leader. Bothered by DMD's position, Spenner often asked, "How can we make HP a major player in the disk-drive industry? Why don't we have 20% market share? How can DMD become the next printer business for HP?" Questions like these sparked Spenner's entrepreneurial spirit. By 1991, he was convinced that a new disk-drive architecture with an innovative design could take the computing market by storm and that HP was the company to create it.

DMD had established itself in the 5.25- and 3.5-inch market but by 1992 had not introduced a 2.5-inch drive of the sort used in notebook computers. Spenner felt the competitors within that market—particularly Conner, Quantum, and Western Digital—were too strong to attack directly and that to succeed, HP needed to go beyond any existing architecture. He believed in Hackborn's favorite maxim: "Never take a fortified hill."

Thus, Spenner wanted to attack an entirely new hill. He envisioned the future of storage in the form of large data library servers fed and utilized by client computers (desktop and notebook PCs) and, in the future, handheld computers. Handheld computers and other very small forms of computing represented an emerging market for which DMD could make a suitably small disk drive. Spenner had found his hill. He wanted a disk drive that not only served the computing marketplace but transcended the traditional market boundaries and could be used in any product that used a microprocessor.

To receive approval to initiate the project, Spenner decided to present the idea directly to Hackborn. He assigned one of his engineers, George Drennan, to scope out different design concepts. Drennan reported back with several differently sized rectangular boxes, each one representing a possible choice for HP's new drive. The largest represented a 2.5-inch drive, the smallest 1.3 inches. Over lunch in early 1991, Spenner placed in front of Hackborn the differently sized boxes, explained his vision of a new disk drive, and asked, "Well, which one shall it be?" Hackborn looked them over and, to Spenner's surprise, picked up the 1.3-inch box and said, "Do this one." This approval was all that Spenner needed. "Hackborn had such respect within the HP organization," stated one engineer, "that once he said 'Do something,' everyone seemed to fall into line." Soon after Hackborn had approved the project, so too did Smelek. At the time, the Computer Products Organization had just reported record earnings for fiscal 1990. Hackborn and Smelek agreed that DMD could afford the

financial risks of the Kittyhawk. Much of the necessary investment could be covered by profits from the division's one- and two-gigabyte products.

The Project Team

Despite Kittyhawk's heavyweight endorsements, DMD's functional management and most of the R&D section managers hesitated to support the 1.3-inch drive. They felt that the investment in a new, small architecture would conflict with the needs of the division to stay atop its established markets. In the race for multigigabyte drives, Seagate and Maxtor were neck and neck with DMD, and the industry's volume leaders, Quantum and Conner, were nipping at their heels. They felt that the division's priorities should be to its next-generation higher-gigabyte product lines, not to a tiny drive whose market was yet unclear.

Spenner had expected this reaction and moved to separate the 1.3-inch project from the rest of the division. Accordingly, the project team moved operations out of DMD's main building into trailers located at a remote corner of the division site. Spenner considered Kittyhawk the division's highest-priority project and afforded the team the power to make timely decisions. One team member viewed Kittyhawk as an engineer's dream project: "We were basically a start-up business with the speed and flexibility of entrepreneurs but with also the financial and technical backing of a successful high-tech company." The project also received executive support from the top ranks of HP. Hackborn and Lew Platt, HP's CEO, often visited the project trailers to see how the development was progressing.

Spenner wanted to make sure that the Kittyhawk was not governed by the division's traditional development processes. In order to speed Kittyhawk to the market, he gave the Kittyhawk team autonomy to develop the drive, find new markets, and cultivate a customer base.

The core project team, formed in May of 1991, contained three functional representatives (manufacturing, marketing, and R&D) with a program manager from R&D, Seymour, as the leader. It was not hard to fill these positions. Spenner looked for risk takers who would be more excited by the market potential of a 1.3-inch drive than by its technological capabilities. These core members were not necessarily experienced in developing new architectures or cultivating emerging markets but were considered to be "can do" people. Seymour had been an R&D section manager for DMD with a manufacturing background in disk-drive heads and media. Although having never led the development of a new architecture, he had the reputation for quick thinking and action that Spenner believed necessary to make the project succeed. Jeff White, the marketing manager, had joined HP a few years earlier with an MBA and had a similar reputation.

As Spenner had with the core of the team, the Kittyhawk's managers carefully chose their staff. Although recruiting from other HP divisions as well, they mostly selected exceptional employees from within DMD. "Because of the priority of our project, if we wanted someone from the division's next-generation two-gigabyte project," said Seymour, "we got him. No questions asked."

The core team was wary of team members who would bring with them HP's cultural biases. To reinforce how differently the team needed to work, David Woito, the project's R&D manager, required all engineers to sign a creed before they could join the Kittyhawk team: "*I am going to build a small, dumb, cheap disk drive!*" Two engineers would not sign the statement and returned to the HP mainstream.

To ensure that the team functioned well, the core team extensively researched team dynamics and group development literature. When setting up their work areas, team members who had to coordinate together had their desks next to one another. "Our organization was a state-of-the-art team," boasted a member.

The Project Parameters

Spenner drafted a project charter for Kittyhawk, which comprised five goals:

1. Introduce the Kittyhawk in 12 months, from start to finish.
2. Accomplish a break-even time (BET) of less than 36 months (see **Exhibit 5**). BET was the time it took to repay the negative cash flow incurred in developing and launching the product.
3. Achieve a $100 million revenue rate in two years after launch.
4. Be the first 1.3-inch drive on the market—"the first on a new hill."
5. Grow faster than the disk-drive market to help HP become a significant industry leader. Thus, revenue growth rate had to be around 35%.

Although aggressive, Spenner's charter did not appear to be out of reach. HP's average cycle time for new disk-drive platform development was 18 months. Because they could leverage off technology that DMD had been developing for its larger drives, the project team believed that they could attain the 12-month introduction date. In addition, although three times higher than had been originally forecast, the $100 million revenue rate was thought to be possible by focusing on and cornering high-growth market areas.

Finding the Kittyhawk Market

One week after the start of the project in June of 1991, Seymour and White arrived at the Consumer Electronics Show in Chicago to look at some market possibilities for the Kittyhawk. They ignored the desktop and notebook computer sections of the show, fortified hills that they were, and searched for the newest mobile computing products—handheld and pen-based computers, otherwise known as personal digital assistants (PDAs). Although still in the fledgling stages of development, PDAs offered some interesting possibilities for a 1.3-inch drive.

After interviewing several leading PDA developers in the mobile computing section, Seymour and White came upon a booth the size of about eight or nine other booths combined—the Nintendo exhibition. There they found a labyrinth of interactive games and turned to each other with the same awestruck reaction: "Look at all the storage possibilities here! We could fit 50 of these games onto one Kittyhawk." They pulled the Nintendo marketing manager aside and asked him if Nintendo might be interested in a new small storage device for its game cartridges. The Nintendo manager replied, "Absolutely, the software writers' dream is to have more cheap storage. We're always looking to create more complex games." He then emphasized that the imperative word here was "cheap," more accurately about $50. As they left, Seymour asked, "How many of these game cartridges do you ship per year?" "Well, to give you an idea," the manager responded, "in the Christmas season we ship about 1.5 million per day."

After returning to Boise, White continued market research for the project. He read research reports on new markets in electronics and contacted companies to explore their future product plans. White also talked to many people within HP itself in his search for insight about where the electronics industry was going to explode. White compiled a list of five possibilities: mobile information technologies, communications technologies, consumer electronics, automotive electronics, and some new developments in standard computer technology.

After considerable deliberation over these target markets, the Kittyhawk team narrowed the strategy for the Kittyhawk down to two possibilities, either a disk drive specifically focused at the

mobile computing market or a drive so inexpensive that it could be used in applications where disk drives previously had not been economically feasible. The team struggled between these two choices. Seymour and White had not forgotten their experience in the Nintendo exhibition, certainly not the "1.5 million" statistic. But at the same time, they also believed that a $50 disk drive, by itself, might not spawn a large market fast enough to achieve Spenner's desired break-even time. The lowest unit cost that had been achieved thus far in the industry for a fully featured disk drive of any capacity was about $130. For the industry as a whole, this $130 seemed to have acted as a cost floor of sorts—it cost that much to purchase and assemble the basic components. Designers were able to reduce the cost per megabyte by persistently increasing the megabytes per drive. But the cost *per drive* seemed to stubbornly remain above $130. Hence, designing a $50 drive would require a significant design breakthrough.

Mobile computing markets would require breakthrough technologies of a very different sort—in particular, the ability to pack more megabytes of information per square inch of disk surface than had even been done in a small drive. But if they could do it, the market seemed attractive. Every company that was developing a PDA showed intense interest whenever White or someone from his marketing staff asked if they could use a smaller disk drive. White noted, "Mobile computing was still in its infancy when the Kittyhawk was being developed. Everyone who knew something about technology thought that PDAs would be the next biggest thing to hit the market." Companies such as Apple, IBM, Motorola, AT&T, and even HP were investing hundreds of millions of dollars in the development of their own PDAs.

Because the mobile computing market volume seemed nearer at hand, the team decided that the best strategy would be to start by designing a drive suited for the mobile computing market and then eventually, through high-volume production, reach the $50 price point through volume manufacturing and next-generation product redesign. From their beachhead in mobile computing, the team imagined a disk drive that would be utilized in all sorts of consumer electronics such as Nintendo game cartridges and cellular phones. They saw it used as a "super" floppy disk, where computer users could carry the Kittyhawk around in their pockets with programs already loaded onto it and be able to sit down at public-access computers, plug in the 1.3-inch drive, and begin using the applications that they brought with them. The team reveled in the possibilities.

Seymour subsequently presented a three-page strategy document to Spenner. On each page, in bold lettering, was printed one objective:

- Lead industry in 1.3-inch form factor.
- Ride the mobile computing explosion to get to low cost.
- "I'll sell you a drive for $49.95."

Seymour explained the simplicity behind these objectives: "This was not a 20-page strategy that you would ordinarily see with a project of this magnitude. Instead, we just wanted people to start to imagine the immense possibilities of the Kittyhawk."

To reassure Spenner that mobile computing represented the right high-growth market for the Kittyhawk, the team contracted with a highly reputable market research firm that specialized in high-tech markets to independently gauge the magnitude of Kittyhawk's opportunity. The firm typically would talk to existing customers and industry experts to analyze where the market was headed. However, in this market, when it was not yet clear who the larger customers would ultimately be, the firm found that its normal methodologies led it nowhere. White recalled, "It was like trying to learn

Swahili without the help of anyone else who knows the language. The research firm ended up talking to us more than anyone else. Naturally, they came to believe what we believed."

As White worked with budding PDA makers, some of the clearest early input came from Dayton Electronics Corporation, a leading computer maker that was developing a pen-based computer to be used as an electronic clipboard by delivery personnel in overnight package delivery companies. Dayton's lead customer had a specification that the computer had to be able to withstand a three-foot drop onto concrete. At the time, the average hard disk drive could withstand a drop, while operating, of about three inches without data loss.

Other of the Kittyhawk's design specifications were taken from HP's Corvallis Division. Whereas most notebook and subnotebook computers employed 2.5-inch drives, the Corvallis Division was designing a "super" subnotebook that would not have space for a 2.5-inch drive. As a result, the Kittyhawk team worked closely with the Corvallis group to meet their operating requirements—particularly, low weight and low power consumption.

Through their work with PDA developers, the Kittyhawk team developed a view about which of the PDA developers would succeed. They felt that those handheld computers that addressed an application-specific niche in the market—such as Dayton's PDA for package delivery—would be more likely to succeed because of the focused functionality they required. Portable check-in devices for car rental companies had similar characteristics.

The Competitors

Seymour and White felt that two technologies might compete with Kittyhawk. The first was flash memory, a nonvolatile integrated memory circuit that retained information stored on it even if the power was turned off. Because it had no moving parts, flash was exceptionally rugged. Although the flash chip commanded about $50 per megabyte, 10 times more expensive than the average disk drive, it became competitive with disk memory at the small end. Six megabytes of flash memory cost about $300. Because of the apparent unit-cost floor for disk drives discussed above, this meant that for very low-capacity drives, flash memory would be more closely cost competitive than for higher-capacity drives. The Kittyhawk engineers considered the dynamics of this competition when deciding that their 1.3-inch drive should have at least 20 megabytes of storage.

The second potential competitor was the 1.8-inch disk drive. Although not yet available when the Kittyhawk project started, industry sources believed that several other companies planned to introduce 1.8-inch models in 1992. Historically, in the progression from 8-inch to 5.25-inch, 3.5-inch to 2.5-inch disks, the surface area per disk in each new architecture was half of the preceding generation's surface area (**Exhibit 6** shows this pattern). Hence, a 1.8-inch drive would be the industry's most predictable next step after the 2.5-inch drive; the Kittyhawk essentially leapfrogged ahead one generation beyond the 1.8-inch form factor. Seymour tended to discount the 1.8-inch threat, however. Though it would have greater capacity, it would be larger and consume more power.

The Product

Seymour deliberately worked to instill fear amongst his colleagues: "I wanted the team to imagine that everyone in the industry was going to beat us to the punch." Integral Peripherals' introduction of the first 1.8-inch disk drive for subnotebook computers in September 1991 spurred the Kittyhawk group to move even faster. "We traded most everything to meet the schedule: performance, features,

cost—everything but reliability," said Seymour. Though Seymour and White felt they probably had a 12-month lead on the competition, they told everyone six months to elevate the sense of urgency.

Designing the Kittyhawk to meet the key performance mandates White's market research had identified—the three-foot drop and 20 MB of capacity, in particular—required that three unique technologies be developed. The first was a new substrate material for the disks. Disks in larger drives generally consisted of polished platters of aluminum that were coated with thin films of magnetic metal. To meet the height requirement of the Kittyhawk, these disks needed to be reduced to the thickness of foil—making aluminum an unsuitably weak substrate. The project team developed, with a supplier, a glass substrate that was thin but strong enough. It could be polished so flat and smooth that heads could fly closer to the disk, allowing data to be packed more densely. Team members believed that this disk technology, combined with other custom components, would allow the Kittyhawk to reach up to 200 MB of capacity by 1995.

The second technology was a new level of integration for the Kittyhawk's electronics. Fortunately, since 1989 a group of DMD engineers had been working on the problem of managing the drive's operations and computer interface within a much smaller number of custom-designed integrated circuits. While a typical 1.8-inch disk drive had 20 to 30 chips, the Kittyhawk team integrated even better functionality on only 5 chips. This meant that the 1.3-inch module would use less power, be lighter, and be manufacturable at lower cost.

The key to meeting the three-foot drop requirement centered on a proprietary six-axis piezoelectric accelerometer. This was a shock-sensing mechanism that could detect impending impact on both linear and rotational axes and caused the drive to revert to a mode that protected against data loss—acting much like an airbag collision sensor on an automobile. Seymour described his initial reaction to the innovation: "The technology was amazing. An elegant design all around. The only problem was that this component alone cost over $10 to make. But, man, was it cool."

The project team decided not to manufacture their drive in-house. They looked instead for an external supplier with proven expertise in miniaturized manufacturing and found a perfect match in Japan's Citizen Watch Corporation. Citizen designed and built an automated production line for the Kittyhawk. Prepared for future growth, the line had a capacity of 150,000 units per month.

The Kittyhawk was introduced right on schedule in June of 1992, exactly 12 months from the beginning of development. Although retired and not having been present at a product launch in 10 years, William Hewlett, HP's cofounder, presided at the press conference announcing the Kittyhawk's launch. It measured 0.4 inches by 2.0 inches by 1.44 inches and weighed about 1 ounce. The Kittyhawk was almost half the total size and one-third the weight of the 1.8-inch disk drives that had been introduced to market just months before. The Kittyhawk announcement garnered more press coverage than any new-product announcement in the history of Hewlett-Packard. The design won several prestigious technology and new-product awards for 1992. CEO Platt developed the habit of carrying a Kittyhawk in his pocket as a conversation piece for customers and analysts.

Seymour was not sure how he felt about all the attention: "The great news was that we were in a project with a lot of visibility. That was also the bad news. We had unbelievable support. If we made the Kittyhawk fly, it would fly high, but if it crashed, there was going to be one hell of an explosion."

HP shipped its first Kittyhawk on June 23, with high-volume OEM pricing at about $250. Based on their read of the market, the Kittyhawk's marketing staff was projecting the next two-year demand from the PDA market to be over 500,000 units. At this pricing, Kittyhawk looked as it if would achieve Spenner's objectives both for revenue rate and break-even time.

The Customers

By July of 1992, the Kittyhawk team had design wins in new PDAs being developed at six computer companies. It appeared to be besting both flash memory and the 1.8-inch drive for the most attractive applications. The team also got design wins in other applications. One example was with a company that utilized the drive as backup storage in the portable check-in devices it made for car rental companies. The demand for the Kittyhawk looked to be on target with the project's goals. What was more, many of these customers at the time were considered to be the bluest of blue-chip companies—Apple, IBM, and even HP itself.

In its third month of production, however, the project hit a road bump. HP's Corvallis Division decided that a 1.3-inch drive would not be able to meet the future storage requirements of its super-subnotebook computers. Even though the Kittyhawk team had plans to introduce a second-generation drive with 40 megabytes, that would still not be enough. Corvallis instead decided to use Integral Peripherals' 1.8-inch drive. Kittyhawk had lost its first major potential customer.

An even bigger road bump was that the PDA market never emerged as expected. For most of the PDAs, Kittyhawk's performance was more than sufficient. But other new technologies upon which the PDAs depended, such as handwriting-recognition software and new integrated circuitry, proved to be inadequate. Literally every PDA manufacturer found its PDA sales to be disappointing, and most withdrew from the market. The handheld computers that were commercially successful tended to be technologically modest, lower-priced devices whose needs for storage could be economically satisfied by flash-memory chips.

But there was never an unambiguous, definitive signal to the team that the PDA market would not materialize. It seemed that for every customer that stumbled, such as Apple with its Newton, another reputable, technologically competent customer stepped up with a different type of PDA that it was confident would hit the right price and performance points in the market. Hence, though Kittyhawk's volume ramp was delayed, prosperity always seemed right around the corner. For example, just as HP announced the Kittyhawk II, with 43 MB of storage and the ability to withstand 10% greater shock and consume 25% less power than the Kittyhawk I, a major computer company, Chicago Controls, designed Kittyhawk into an industrial pen-based device for recording and analyzing data for statistical process control in manufacturing plants. Kittyhawk's ruggedness was attractive because stored data would remain intact despite any rough handling that might occur on the factory floor. Microsoft was creating a version of its PC operating system with graphical interface for this particular PDA. The requirements were that the operating system had to be able to fit on the soon-to-be-introduced 40-megabyte Kittyhawk and still leave enough capacity for other programs. White's own research with end users supported Chicago Controls' enthusiasm for this product; if it took off, it alone would catapult Kittyhawk back on plan.

To bolster HP's commitment to Kittyhawk, Seymour brokered a meeting between Spenner, Smelek, and Chicago Controls' CEO, and it worked. They left reassured with the Kittyhawk's potential. Shortly after the meeting, however, Microsoft announced that its operating system for this application would need more than the 43 MB of storage the Kittyhawk offered. This derailed the whole concept of this PDA for factory control.

Even while prosperity kept looming around the next corner in mobile computing, several unexpected customers started to show interest in HP's 1.3-inch drive. The first was a Japanese company whose portable word processor printed Japanese *Kanji* (Chinese characters) when words were spelled on its keyboard. The device was used in both the home and office. It required a storage device that not only had enough capacity to store the necessary translation programs but also could withstand the shocks to which portable devices were exposed. The Kittyhawk's shock resistance also

attracted manufacturers of cash registers. Most of the newest cash registers were run through an operating system that recorded daily transactions within a central computer system. The manufacturers were looking for a storage drive that could act as a backup if the central computer failed while also being able to withstand the shock from the slamming shut of the cash register drawer. The 20-megabyte Kittyhawk served the needs of both these applications perfectly.

Another customer saw the Kittyhawk as a "film cartridge" that could be removed from the digital camera it was developing and inserted into viewing and printing devices. The Kittyhawk's shock resistance was particularly attractive for this application. The camera's success depended on two enabling technologies. The first was rugged storage. Although flash memory could solve this piece of the puzzle, the Kittyhawk served the need better due to its lower cost per megabyte. The second technology was a charge-coupled device (CCD) that transformed images into digital format. The CCD technology ultimately proved technically feasible, but unfortunately its cost pushed the camera's retail price to $1,500, where unit volumes were disappointing.

As a result, the list of Kittyhawk customers (shown in **Exhibit 7**) was very different from what the team had originally planned.

A New Beginning?

Despite this string of disappointments peppered by a few successes from unexpected quarters, interest in the Kittyhawk kept rolling in to White's marketing team—interest from highly credible companies with solid new product ideas. These seemed to fall into two groups. The first were those described above for which the Kittyhawk's ruggedness based upon its accelerometer technology was its most prized attribute. The second group of potential customers was sounding a very different theme: they needed a cheap, simple drive priced at around $50.

"It took a couple of years of the Kittyhawk being in the marketplace before people figured out what they needed," White recalled. "Before the Kittyhawk, most of our customers never even thought about disk storage as a way to improve their products. The Kittyhawk got them thinking, and then they started coming to us with what they really wanted." Nintendo, for example, showed the Kittyhawk team an entertainment system they had already designed, unbeknownst to HP, with a slot for a Kittyhawk drive to be plugged in—a module that could contain many more games, with much more sophisticated graphics, than Nintendo's conventional cartridge approach. "The system is all set," the Nintendo representative persuaded. "All you have to do is sell us your drive for $50." When White protested that the Kittyhawk's accelerometer alone (required for shock resistance) rendered the $50 price impossible, Nintendo responded that they did not need the accelerometer—they just needed 20 megabytes at $50, cheap and simple.

A fax-machine manufacturer explored with the team the possibility of offering an embedded Kittyhawk as an option in its high-end model to handle graphics-intensive transmission. "I learned pretty early on that you don't want to be designed in as an option," White recalled. "You want to be part of their standard product, or you have no way of forecasting what kind of volume you're looking at." White pointed at one of the customer's lower-priced fax machines and asked how many of those they sold. To the answer of 5 million units per year, Seymour responded, "That's interesting. Could you use the Kittyhawk for those?" The customer reviewed his materials list and answered, "Sure, as long as you can deliver the drive to us for $48." "How about if we hit $100?" Seymour queried. The customer shook his head and said, "If you hit $52 we still couldn't use it." White recalled 10 other companies with similar propositions at the $50 price point.

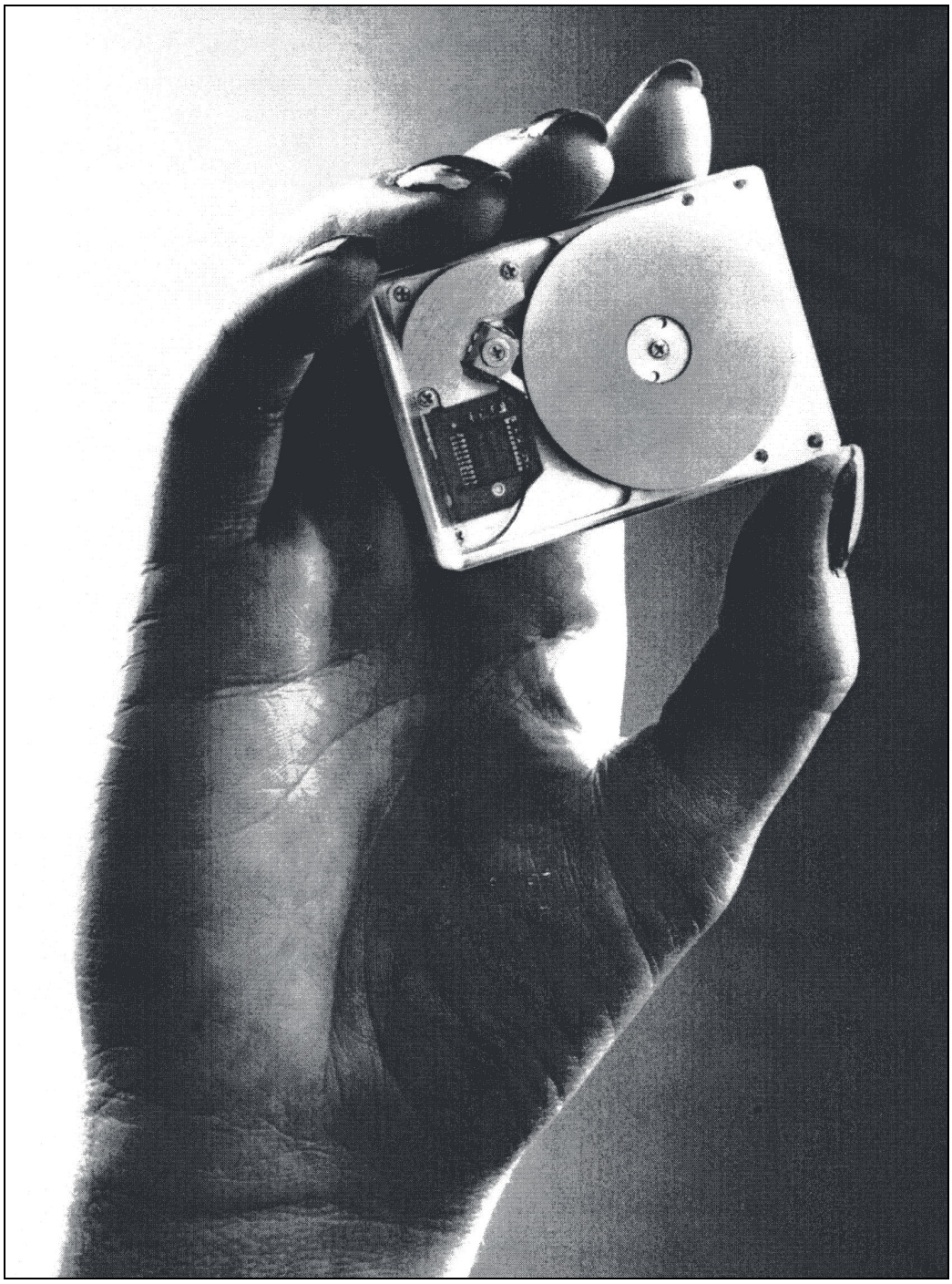
In mid-1994, Seymour convened a meeting of the Kittyhawk core team to determine their response to these developments. Three alternatives emerged from the discussion. The first was to continue to pursue the ruggedness-based applications that were beginning to coalesce. The problem with this strategy was that the ramp to high volumes was sure to be slow and unpredictable, because the customers generally were pursuing new applications themselves, and their success depended on many developments besides the Kittyhawk. The team was losing its confidence that such a business could get big enough fast enough to merit continued interest from HP management.

The second option was to leverage the ruggedness and electronics integration technologies the team had developed to create a superior 2.5-inch drive for notebook computers. This would pit HP against formidable, high-volume competitors such as Quantum, Conner, Seagate, and Western Digital in the mainstream market. But some team members felt HP could become a viable player at the high end of that market, earning enough of a price premium for its ruggedness that it could be a profitable competitor.

The team felt most enthusiastic, however, about the third option—a $50 drive. "Designing something so cheap and simple would be a huge challenge," Seymour predicted. "But with what we learned the first time around, we felt we could do it. Designing a 40 MB 1.3-inch drive that could drop three feet onto a concrete floor was no simple feat, either. The $50 drive would be a very different challenge, but it probably wouldn't be more difficult."

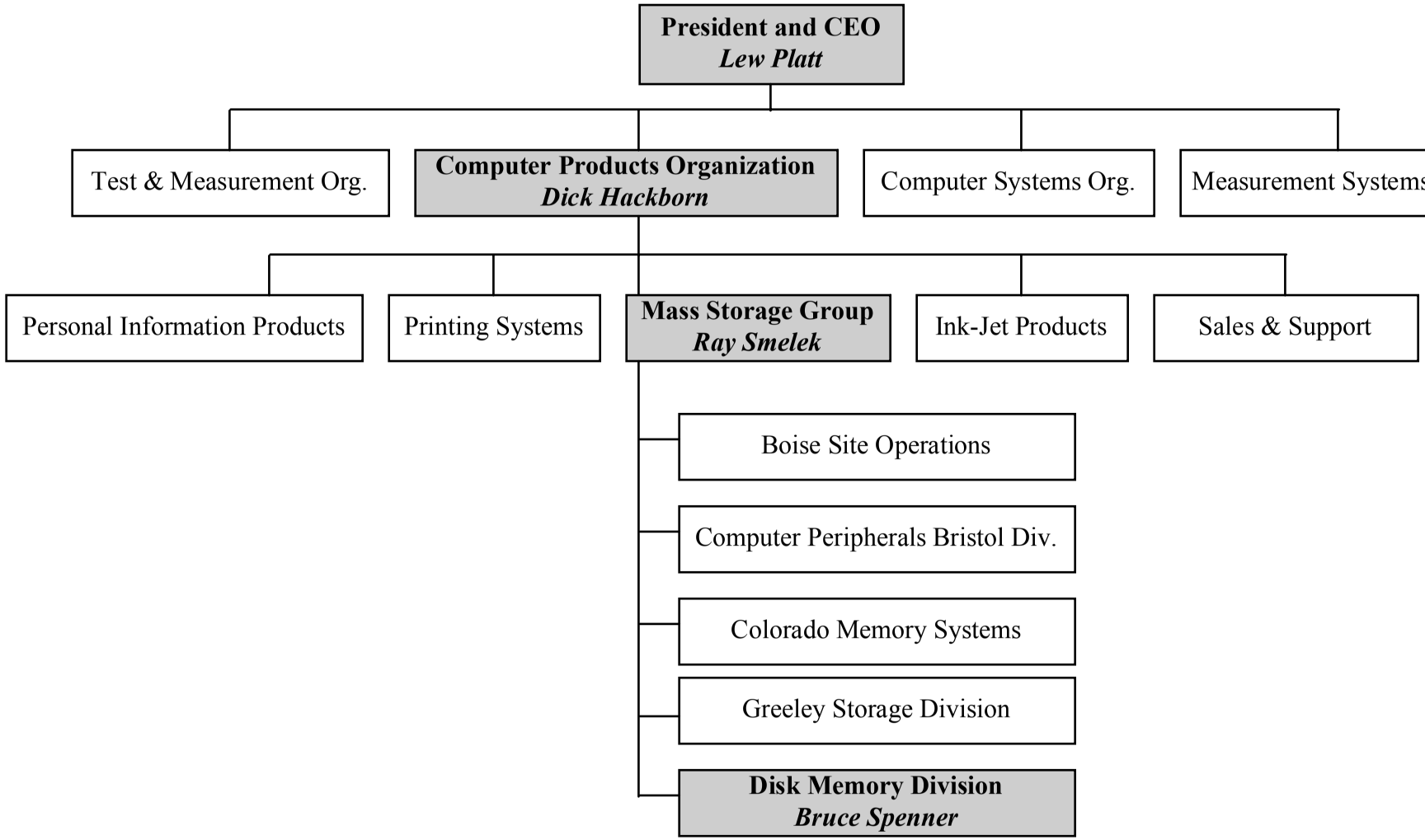
Seymour had a regularly scheduled monthly review meeting with his boss, Spenner, for the following week and felt that he needed to make a firm recommendation on how to proceed or risk having that decision made for him by Spenner or his boss.

Exhibit 1 The Hewlett-Packard 1.3-inch Kittyhawk Disk Drive



Source: Hewlett-Packard.

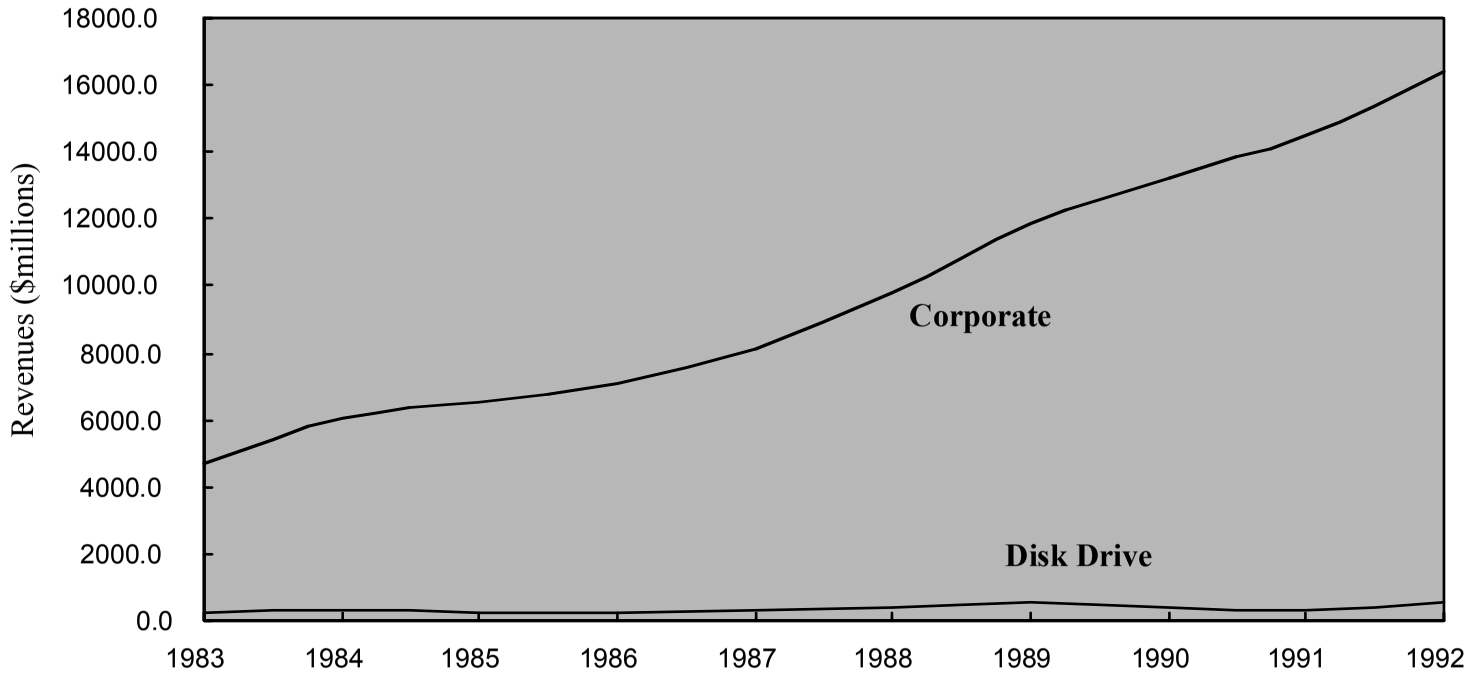
Exhibit 2 HP's Mass Storage Group Organization Chart (1992)



Source: Casewriter.

Exhibit 3 HP Corporate Net Revenue versus Disk-Drive Revenue, 1983–1992 (fiscal year ends October 31; $ millions)

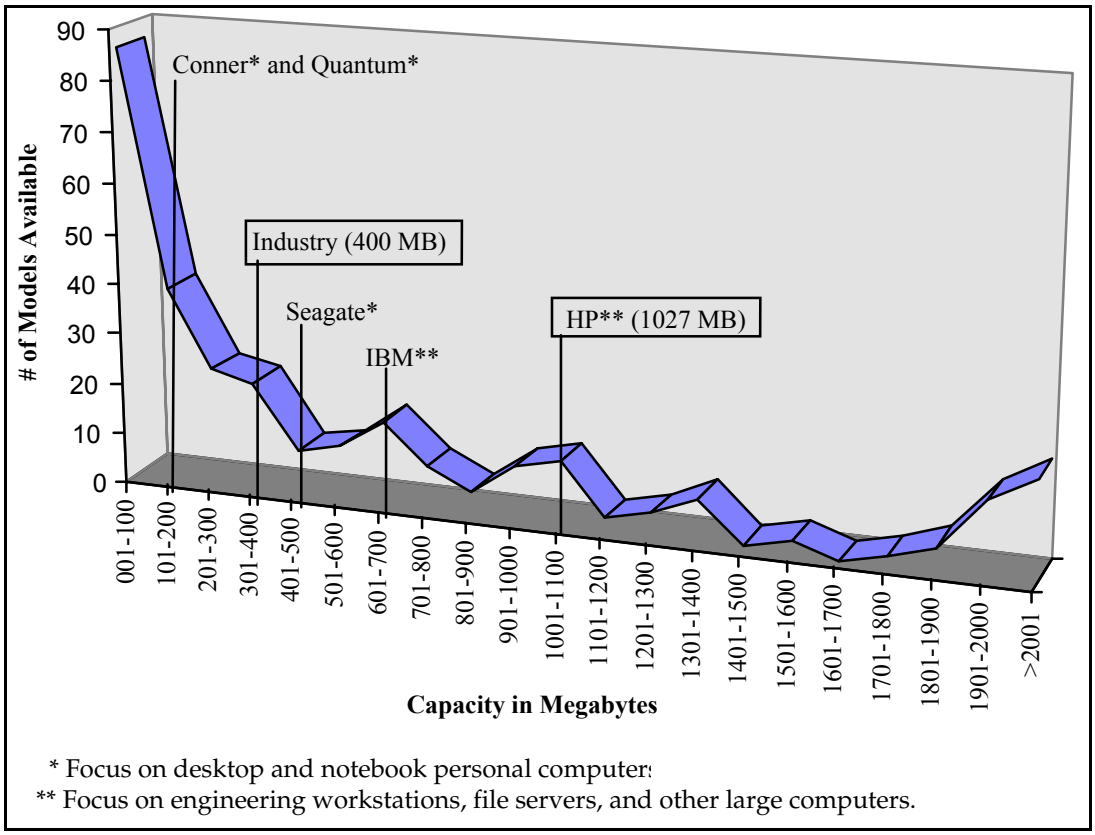
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Corporate Net Revenues	4,710.0	6,044.0	6,505.0	7,102.0	8,090.0	9,831.0	11,899.0	13,200.0	14,494.0	16,410.0
Disk-Drive Revenues	269.1	315.5	259.1	251.3	328.1	420.6	533.4	402.2	280.7	519.4
Disk-Drive Revenues as a Percentage of Corporate's	5.7%	5.2%	4.0%	3.5%	4.1%	4.3%	4.5%	3.0%	2.0%	3.2%



Source: Disk/Trend and Hewlett-Packard corporate reports.

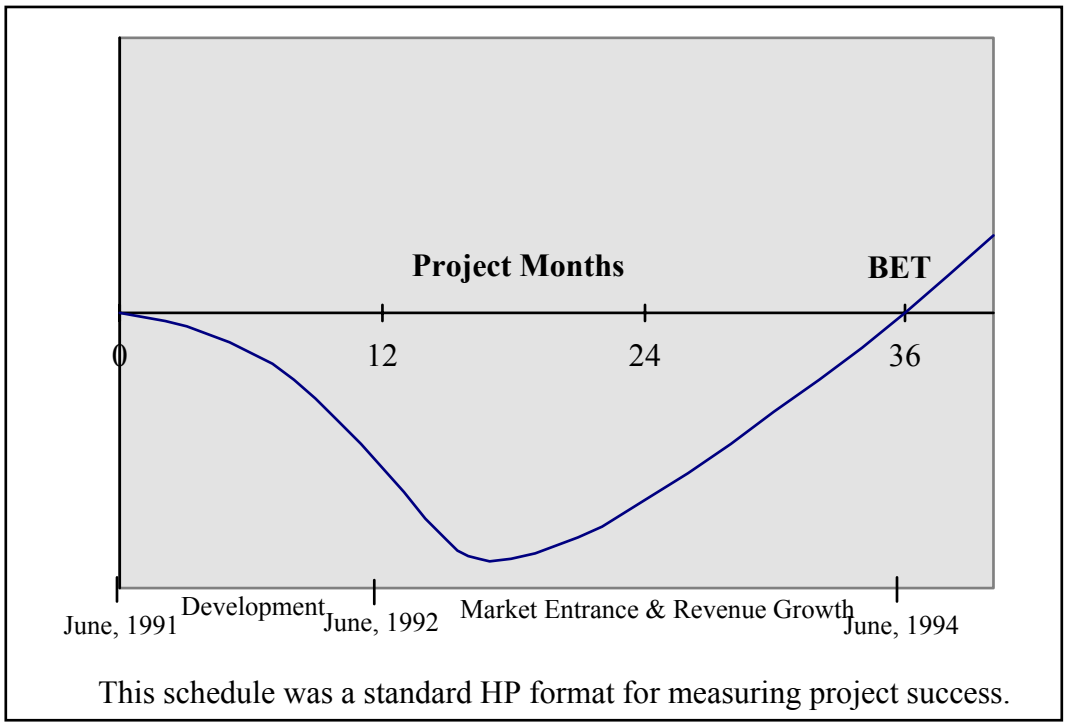
Exhibit 4 A Comparison of HP's Product Position, Relative to Other Leading Disk-Drive Makers

(Vertical lines indicate the capacity of the median model sold by DMD and principal competitors, compared to the industry.)



Source: 1992 Disk/Trend report.

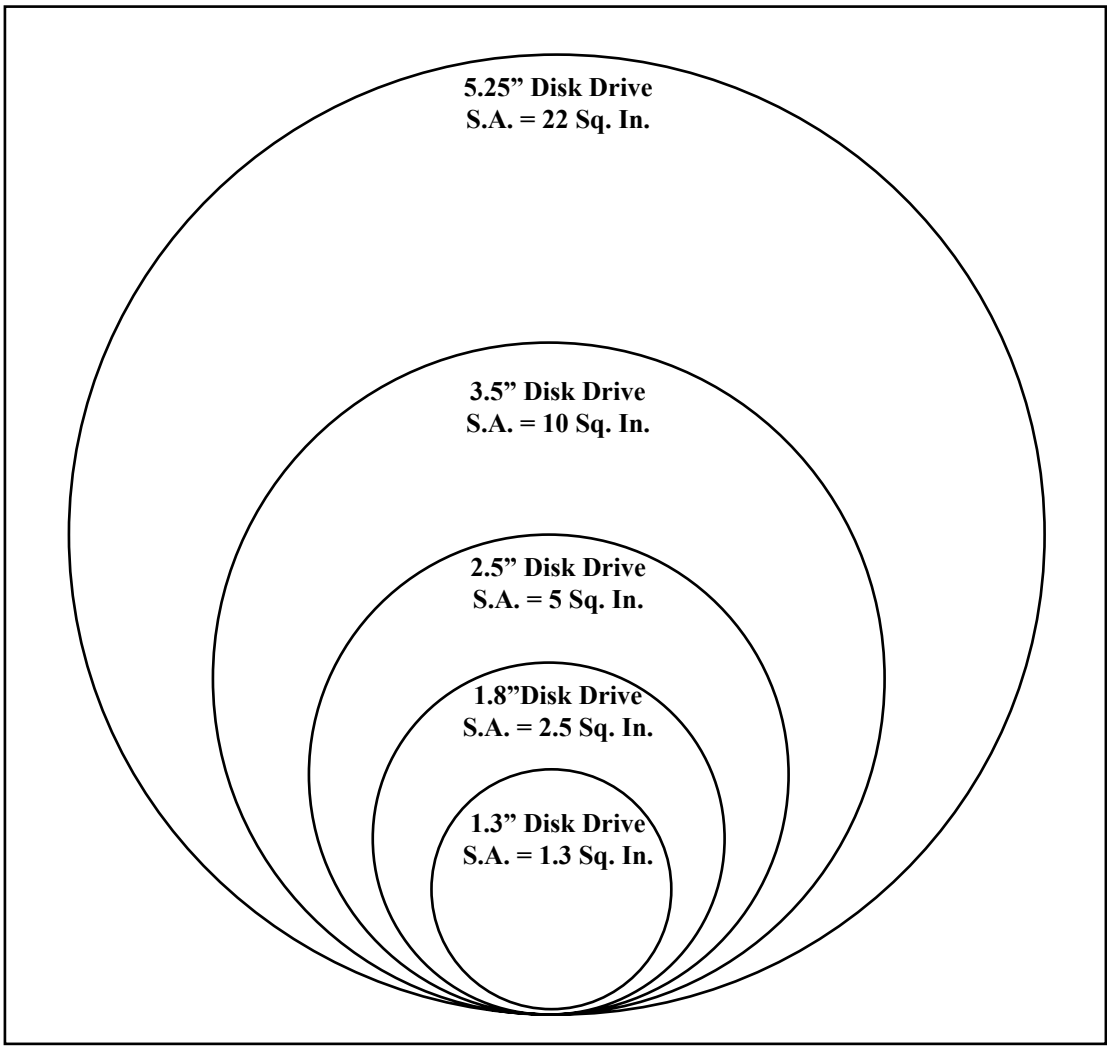
Exhibit 5 Hewlett-Packard's Method for Evaluating Project Success: The Break-Even Time Calculation



Source: Casewriter.

Exhibit 6 The Pattern in Reduction of Disk Surface in New, Small Architectures

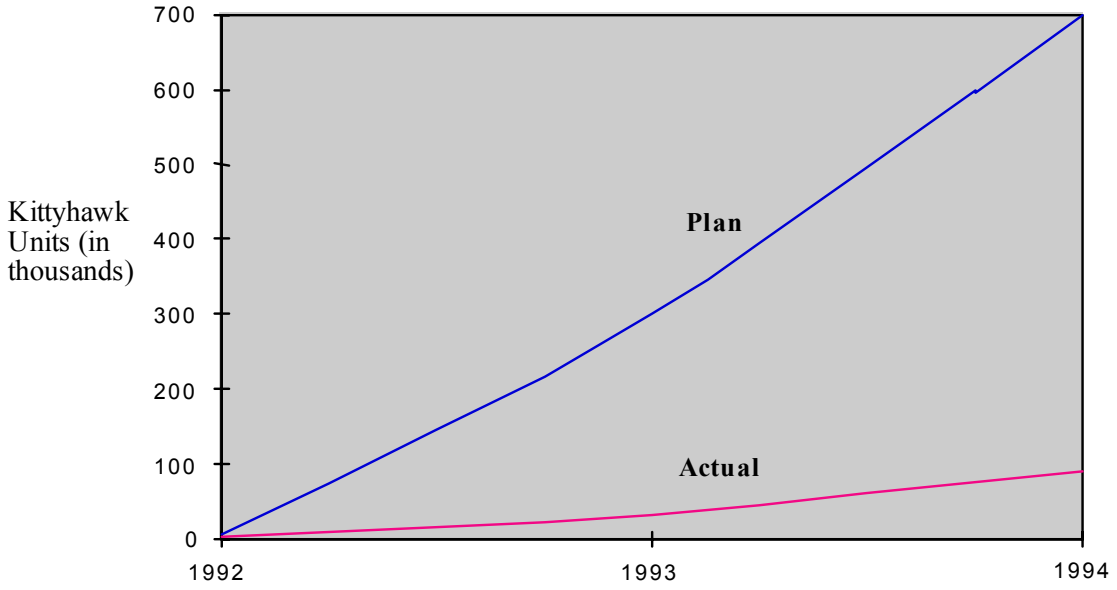
Surface Area = R^2



Source: Casewriter.

Exhibit 7 Planned versus Actual Production Levels and Product Applications

Planned Versus Actual Production Levels



Planned Versus Actual Major Product

Plan:	**Actual:**	**# of Units Sold Over the Life of the Project (000s):**
•Personal Digital Assistants	•Japanese Word Processors	100
•Sub-notebook	•Personal Digital Assistants	35
•Hard Copy Devices	•Digital Cameras	20
•Printers	•Cash Registers	8
•Copiers	•Telecomm. Switching Systems	2
•Fax Machines		

Source: Casewriter compiled from company documents.