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LINKING TECHNOLOGY AND BUSINESS STRATEGY

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Chapter 1

The Strategic Challenges of Technology

Chief executives and other corporate executives who do not have a background or experience in science or engineering look at technology—especially at fast-moving modern "high-technology"—with a mixture of awe and distrust. They see technology as an expense or, at best, a high-risk investment, with uncertain returns in dollars and timing. They also see their best technologists as brilliant and creative people but often more loyal to their profession than to their company and, therefore, hard to direct toward their company's strategic and financial goals.

On the other hand, those officers and managers with strong academic and operating credentials in R&D and engineering view high technology as the primary vehicle for solving the business problems of their company, for strengthening the local economy, and for helping their nation's global competitiveness. They are frustrated if they are asked to justify expenses in technology according to standard business criteria, such as return on investment, arguing that technology is different and, therefore, cannot be evaluated only in financial terms.

Unfortunately, dialogue between these two cultures is limited. This lack of common understanding of the role that technology can take as a *key strategic resource* of the corporation could impede its becoming a *strategic asset* if properly managed.

Every firm has at its command a finite quantity of resources, both tangible and intangible, such as human resources, plant and equipment, capital and access to funding, customer and supplier goodwill, and corporate image. Management's responsibility is to acquire, develop, integrate, husband, and apply these scarce resources to fulfill corporate objectives and goals, both financial and nonfinancial.

Technology is one resource that, like capital, can be developed or acquired, stolen or wasted, disposed of or applied for growth and profitability. However, technology has some unique characteristics that must be clearly understood by management.

Unique characteristics of technology

First, my definition of technology: a body of knowledge, tools, and techniques, derived from science and practical experience, that are used in the development, design, production, and application of products, processes, systems, and services.

Two important points in this definition should be emphasized:

1. Technology is derived from both science and experience; that is, *both theory and practice are prerequisites of success.*
2. Technology (in contrast to science) *has no value unless it is applied,* normally to create wealth and improve the quality of life.

In contrast to capital, which has a common denominator—the dollar—and, if properly invested, maintains its value with time, technological resources are hard to define and safeguard and, therefore, difficult and risky to manage. Here are some of the unique characteristics of technology:

— **Is highly specialized and fragmented.** At least 50 "key" technologies from ten disciplines are taught at the Center for Integrated Electronics of Rensselaer Polytechnic Institute, for example.

— **Is highly perishable.** One well-established technology may be unexpectedly and rapidly replaced by a superior technology. For instance, half-life of some processes used in the manufacture of VLSI—very-large-scale, integrated micro-electronic chips—is three years, often insufficient to obtain an adequate return from the heavy investment in R&D, plant, and equipment.

— **Must be continuously developed** to keep up with the state of the art. To cite an example, a few years ago, the U.S. micro-electronics industry was the undisputed world leader in RAM—Random Access Memories. After reducing its R&D efforts, the U.S. industry lost a major market share to superior Japanese technology, which had achieved higher yields and quality.

— **Entails high risks and requires significant time spans in development and application.** The probability of *financial* success of a technological innovation is about one in three and positive cashflow may not be obtained for three to 12 years depending on the nature and diffusion rate of the technology. (The information services industry corresponds to the shorter time periods, the proprietary pharmaceutical and biotechnology industry to the longer time periods.)

— **Is transferred by people, not by paper.** While money and financial information is easily transferred by standard procedures according to accepted accounting practices, technological documentation is never complete. Therefore, continuous interaction of people is necessary for an effective transfer of technological know-how, as witnessed by the problems of transferring advanced technologies to developing countries.

— **Is enhanced, not reduced, by multiple users.** With appropriate feedback, diffusion will contribute to new technological developments and applications. Therefore, there are *no theoretical limits to the growth* and the increased utilization of technology to create added value and wealth.

Three new strategic challenges

The recent evolution of technology presents three new major strategic challenges to the corporation.

1. **Technology explosion.** Man has been generating technology at a slow but steady pace since the beginnings of civilization, 10,000 years ago. However, since 1935 technology has exploded, with the result that 90 percent of what we know now has been generated during the last 55 years. Ninety percent of all scientists and engineers who ever lived are living and working now. The rate of generation of new technology, as measured by the number of scientific and technical journals for instance, continues to grow at an exponential rate. This means that our technological knowledge will probably be doubled during the next 30 years.

The strategic challenge is: How can a company keep up with the technologies which will influence its competitive position?

2. **The shortening of the technology cycle.** The classical technology cycle starts with a scientific discovery and ends with the diffusion in the marketplace of products and processes embodying the new technology. For instance, let us look at polyvinyl chloride (PVC) products. The scientific disciplines underlying this technology are chemistry of free radicals, rheology of polymers, and chemistry of vinyl compounds. From these disciplines emerged new technologies: extrusion of thermoplastics and formulation of PVC resins. In turn these technologies are embodied in PVC products, either as sheets or extruded pieces—for instance, plastic foils for wrapping food products, inflatable toys, and plastic plumbing pipes. Thus, for many technological innovations we can measure the time lag between scientific discovery and introduction of the product in the marketplace. This time lag is becoming shorter. For instance, it took 112 years to develop photography from the discovery of the basic physical phenomenon, 56 years for telephony, 35 years for radio, 12 years for television, and only three years for the transistor and engineering plastics.

The strategic challenge is: How can a company incorporate a new technology into a new product and reap commercial and financial benefits before this product is made obsolete by a newer, better technology?

3. **Globalization of technology and international competition.** Bruce Merrifield, U.S. Assistant Secretary of Commerce for Productivity, Technology and Innovation, estimates that in 1975 the United States, with only 5 percent of the world's population, was generating maybe 75 percent of the world's technology, and that our share is now down to 50 to 55 percent and in another decade it will only be one-third. While the U.S. continues to generate technology at a modestly increasing rate, other countries in the world, starting with Japan and Germany, are generating technology at a much faster pace. In addition, with the modern information age, transfer of technology between countries, regardless of barriers and controls, is proceeding at a faster pace, as witnessed by high-tech consumer products, such as the VCR, originally developed in the United States and now coming to the U.S. in much improved versions from Japan and other countries of the Pacific Rim.

The strategic challenge is: How can a U.S. company remain technologically and commercially competitive in the world's marketplace by fighting foreign competitors in the home and overseas markets?

Chapter 2

The Technology Input/Output Process

MANAGEMENT'S RESPONSIBILITY is to acquire or develop the resources necessary to carry out the mission of the firm. For instance, required capital may be raised through the sale of securities or borrowings from financial institutions, or it may be developed within the firm, through retained earnings.

The *technology input process* is conceptually the same. Technology may be developed in-house, through R&D, or may be acquired from outside the firm in various ways, for instance through:

— Contracted-out R&D to research institutes, such as Battelle or Stanford, or to technical universities.
— Joint R&D programs at universities. (A typical example is the RPI Center for Interactive Graphics that carries out advanced research for 38 sponsoring or member companies, with 50 researchers and an annual budget of $2 million.)
— Joint research corporations owned by the member companies. These have become possible since the lifting of some anti-trust restrictions. Spurred by threat of Japanese competition, such corporations have been formed for computer and semi-conductor research with staffs of several hundred and budgets of several hundred million dollars.
— Hired experts, such as independent consultants, professional inventors, and university professors.
— Licensing-in of technology, by acquiring exclusive or nonexclusive rights to patents and proprietary knowhow developed by other companies or individuals.
— Acquisitions of companies or business units for the specific purpose of obtaining the technology, rather than the assets, markets, customer goodwill, and the like. Many young biotechnology companies have been acquired for this purpose. Since technology, as stated above, is transferred by people, provision should be made to retain the key researchers after the acquisition, because their de-

parture would make the purchase worthless.

— Acquisition of components or subassemblies that are incorporated into the company's products and sold under the company's trademark. For instance, many personal computers use as "brains" the microprocessor chips of leading producers of semiconductors.

By in-house development or through acquisition, the corporation creates a base of *technological assets*, which must be safeguarded, just as tangible assets, from theft, waste, and obsolescence. As we have seen, obsolescence is probably the most serious threat to high-technology industries.

Unless they are properly utilized, the firm's assets will not produce benefits, growth, and profitability. Therefore, in order to produce wealth, technology must be applied through the *technology output process*. In the input process, the corporation had two basic alternatives: make or buy. In the output process, there are two corresponding alternatives: incorporate or sell. Thus, the company technology assets may be:

— Incorporated in new or improved *products, systems,* or *services* that are offered to the markets. (For instance, General Electric has created a multi-billion dollar business in plastics and silicones from its R&D efforts.)

— Incorporated in new or improved *processes* utilized by the company to increase capacity, reduce costs, improve quality, and the like. (An example is the General Electric proprietary process for producing "man-made" industrial diamonds.)

— Sold through licensing-out the patents and proprietary knowhow.

— Utilized in joint ventures with other companies.

Measuring the efficiency and effectiveness of the process

The technology input/output process is shown in Figure 1. To measure its efficiency and effectiveness, we begin by measuring the *efficiency of the input process*. This is measured this way:

$$\text{R\&D Productivity} = \frac{\text{Technological Assets}}{\text{Input Investment}}$$

The *effectiveness of the output process* is then measured in terms of

$$\text{R\&D Yield} = \frac{\text{Net Present Value of Output}}{\text{Technological Assets}}$$

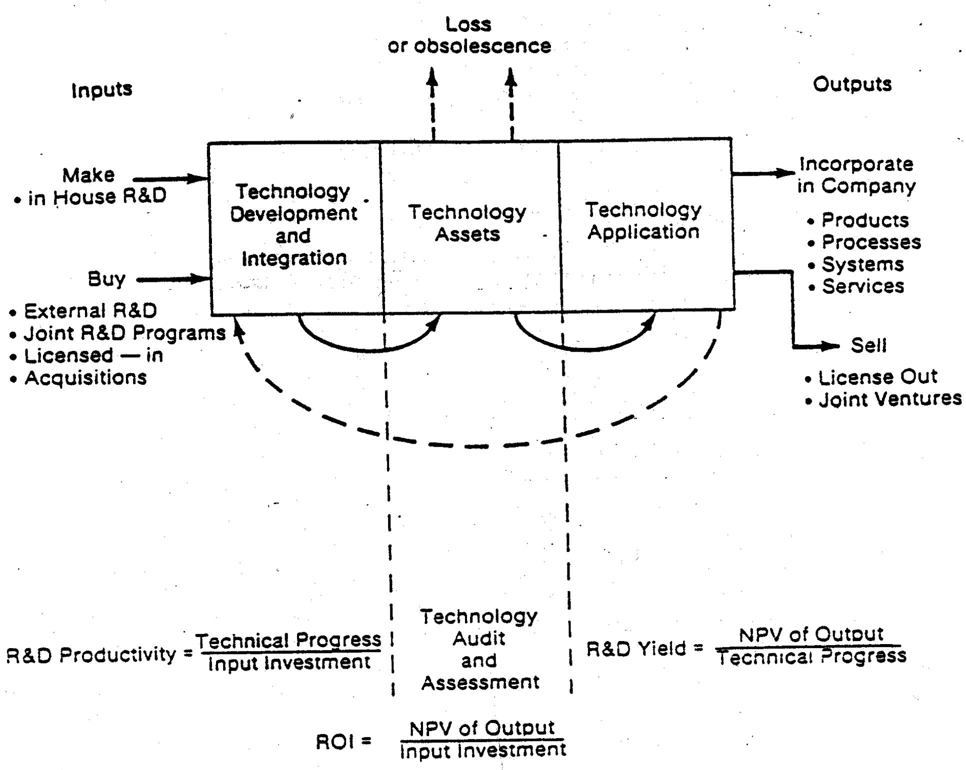
In the two ratios above, input investment and output are measured in financial terms. The input is the sum of salaries and expenses of the researchers, depreciation of plant and equipment, overhead, and so forth, or the amount paid to acquire the technology. The output is the sum of the profits accruing from the new product (or process) over its lifetime. Since, as we have seen, there may be a time lag of several years between input and output, all computations should be done on the basis of net present value.

Technological assets are difficult to estimate in financial terms, although an assessment can be made of the market value of patents and proprietary knowhow. It is therefore easier to multiply the two ratios above to eliminate the "technological assets" term and compute directly the return on investment (ROI) of the total technology input/output process.

$$\text{ROI} = \frac{\text{Net Present Value of Output}}{\text{Input Investment}}$$

Studies by prominent researchers show ROI ratios of 50 percent, 40 to 60 percent, and 33 percent per year, respectively for the chemical industry, the petroleum industry, and 42 companies or stra-

Figure 1 The Technology Input/Output Process



tegic business units of the PIMS data base. Therefore, R&D is an activity that yields high overall return on investment, commensurate with the inherent high risk.

We should not forget that the apparently simple ROI ratio above is the product of *two* separate ratios: R&D productivity times R&D yield. Therefore, in order to maximize ROI it is necessary to maximize *both components* at the same time.

Some organizations are deservedly famous for their R&D productivity. Bell Laboratories, for instance, has an enviable record of seven Nobel laureates and outstanding scientific and technical publications. Yet its R&D yield has been, up to now, quite low given the problems and financial losses of AT&T technologies after they started competing in the open marketplace.

Conversely, many Japanese companies are not known for their high R&D productivity but have been very smart in acquiring (rather than developing in-house) technological assets from the United States. They have also been extremely efficient in incorporating their technologies into superior high-quality products, from satellite communication systems to consumer electronics. Clearly, we can learn from their efficiency.

The General Electric Company has a remarkable record in terms of both R&D productivity and R&D yield. If R&D productivity is measured in terms of patents per professional researcher, the GE R&D Center boasts a ratio that is five times that of the more famous Bell Laboratories. The high R&D yield is evident by the fact that one dollar spent by the GE R&D Center produces, on the average, four dollars of profits from new products, and that the profitability of these new products is double that of the established product base.

In conclusion, corporate management and staff must optimize both the technology input and output process. The first can be done by motivation and business direction of the R&D people, the second by ensuring efficient technology transfer from the R&D laboratories to the operating units.

We will discuss now the criteria for selecting the most appropriate technology acquisition and technology utilization modes.

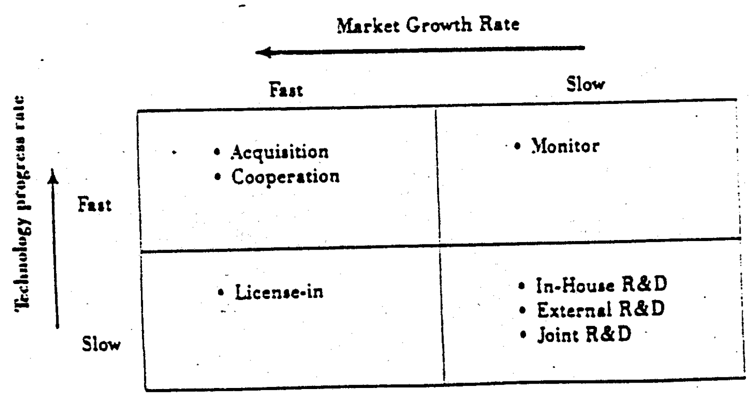
Technology acquisition: Make or buy?

Many corporate officers believe that technology developed through in-house R&D is superior and more prestigious than acquired technology. This is not always the case: the "make or buy" decision depends on the rates of market growth and of technological progress, as shown in Figure 2.

Let's look at four different situations in terms of the "make or buy" decision:

1. If the rate of technical progress is slow, *and* if the rate of market growth is moderate, *and* if there are significant barriers to possible new entrants, *then in-house R&D* is the preferred solution. The reason is that R&D, if successful, will result in a temporary product or process monopoly that the company can exploit to maximize market share and profitability. A classic example is GE's research into the behavior of elements under

Figure 2 Technology "Make or Buy" Selection Criteria



extremely high pressures and temperatures, which yielded "man-made" industrial diamonds. Although the original patents, granted in the 1950s, expired many years ago, GE maintains its market leadership, thanks to proprietary process knowhow. An alternative to in-house R&D, which is becoming more popular, is to contract for external research or to participate in joint R&D programs, carried out by universities, independent laboratories, or joint research corporations. This, of course, means sharing the results of R&D with others, who may be competitors, and reduces the company's strategic advantage in the marketplace.

2. If the technology is moving rapidly and the market is moving slowly, a major effort in R&D may be very risky, since it may lead to development of an ultimately obsolescent technology or of one for which there is no market. A more prudent strategy is to *monitor* the various competing technologies and keep abreast with their progress, in order to be ready to move as soon as the winner emerges. (We will discuss technology monitoring and forecasting in Chapter IV.)
3. If the technology is moving slowly and the market is moving fast, there is not enough time for inhouse development. The appropriate strategy is to *license-in* the technology. This should be done on an exclusive basis if the barriers to entry are high, and on a less expensive non-exclusive basis if the barriers to entry are low. In some cases, acquisition and exploitation of licenses may lead to technical independence. For instance, a French electrical manufacturer initially acquired pressurized-water nuclear reactor licenses and knowhow from Westinghouse. Progress was rapid, and France now generates 70 percent of its electrical power from nuclear power plants and is considered the world's leader in this technology. The license has now been converted into a joint technical cooperation agreement. Similarly, the Japanese "miracle" was based on a massive acquisition of licenses that were then used as the basis for in-house R&D (initially mostly development). Through this strategy, the Japanese licensees were able to catch up with their licensors and, in several cases, to overtake them technologically and commercially, as evident by the demise of the $8 billion U.S. consumer electronics industry.
4. If both technical progress and market growth are fast, the licensing-in solution may lead to acquisition of an obsolescent technology. In that case, it is better to *acquire a company or business unit*, one that is well established in the field, to obtain the benefit of its knowledge of the market and of competing technologies.

A complementary way to look at the various modes of technology acquisition is to consider:

— The degree of *strategic advantage* available to the company after implementation. This strategic advantage depends upon the degree of autonomy in utilizing the technology (for instance, licenses and cooperation agreements may have restrictive geographic or application clauses) and upon the uniqueness of the technology (for instance, other licensees or

partners in joint R&D programs will have access to the same technology).
— The *time delay* needed to incorporate the technology into the company's assets and thus to be ready for implementation.
— The relative cost of acquiring the technology.
— The relative risk that the acquired technology cannot be incorporated in the company's assets and implemented (for instance, General Electric acquired a small entrepreneurial company specializing in liquid crystal displays, but the key technical people left before the technology could be incorporated into GE's products).

The technology acquisition modes discussed above are ranked in the table below according to these criteria. Obviously, there is no "best" mode. The final choice will depend on both the environmental conditions, as discussed above, and the importance and role of the specific technology for the company's business strategy, as will be discussed later (Chapter VI).

Technology utilization: Incorporate or sell?

Normally a company can obtain maximum returns from its technological assets by incorporating the technology into its products, processes, and services. Strategies and modes for this internal utilization of technology are the main themes of this study and will be discussed in detail in Chapters V and VI. There are, however, cases where it may be more advantageous, even necessary, for a company to sell its technological assets. Here are some examples of such situations:

— Technological assets may have been acquired that do not fit into the company's business scope and strategy. (GE Nobel laureate Ivar Giavaer obtained several patents for the detection of infectious diseases. Since GE is not a pharmaceutical business, it decided to sell these patents to a new biotechnology venture, Bioquest International, in exchange for a minority equity position.)
— There are markets that the com-

Table
Ranking of Technology Acquisition Modes

Mode	*Strategic Advantage**	*Delay***	*Cost***	*Risk***
In-house R&D	1	7	6	2
Acquisition of a Company	2	3	7	5
External R&D	3	4	4	3
Joint R&D	4	5	3	4
Cooperation Agreement	5	6	5	6
License-in	6	2	2	1
Monitor	7	1	1	7

*Rank: 1—highest 7—lowest
**Rank: 1—lowest 7—highest

pany cannot attack directly because of custom barriers, closed distribution networks, or the like. (Westinghouse, for example, could not manufacture nuclear reactors in the United States and import them into France because the only customer, Electricité de France, was owned by the government and purchased only equipment manufactured in that country. Therefore, Westinghouse had to license a French manufacturer and later convert this license into a technical cooperation agreement.)

— Licensing may be utilized as a strategy for "controlling" powerful competitors and encouraging them not to develop their own proprietary technologies. (After the introduction of "man-made" diamonds, for instance, GE offered a license to its major competitor, DeBeers, which mined and sold diamonds to both the jewelry and industrial markets. DeBeers elected to acquire the GE process rather than face the high cost, time delay, and risks associated with developing its own.)

— By offering licenses to a large group of actual or potential competitors, a company may encourage the industry to adopt standards consistent with the company's technology and thus gain leadership in the industry and world market. (To illustrate, in order to establish the VHS as the dominant video standard, Matsushita licensed companies in many countries. A similar approach is being adopted by two rival groups of U.S. computer manufacturers to standardize their UNIX operating systems.)

— To assure a more reliable supply of components, companies may exchange their technologies with other technologies of interest to them. (For instance, several microprocessor companies "swap" technologies in order to practice double-sourcing through cross-licensing.)

— Cross-licensing between corporations may ensure access to new or improved technologies and avoid expensive lawsuits for patent infringements. (For example, GE and IBM and GE and AT&T have exchanged licenses in several technologies not directly related to their principal product lines.)

Chapter 3

The Optimum Investment Level in Technology

When asked "How much should the company invest in technology?" many corporate managers and staff members, particularly those with a scientific or an engineering background, reply, "The more the better!" or "All that we can afford!" Such a strategy, while apparently praiseworthy, does not always lead to optimum growth rates and financial returns for a corporation. In practice, the optimum investment level depends on more detailed considerations, such as the nature of the industry and the market position of the company or business unit. (Technological strategies and their effect on R&D investment will be discussed in Chapter VI.)

Nature of the business

Technology-intensive industries (also called "high-tech" industries) are characterized by two factors: (1) a high R&D expense/sales ratio, from 5 percent to 20 percent, and (2) a high ratio of technical to total employees (for instance, one out of ten). Typical are the aerospace, instruments, pharmaceutical, computer, optical, and electronics industries. In contrast, in technology nonintensive industries (also called "low-tech" industries), the corresponding ratios are much lower: from less than 1 to 3 percent in R&D expense sales or only one technical employee out of 50 or 100. Typical industries are food processing, textiles, cement, wood products, and rubber. Thus, the first benchmark for setting the level of a company's R&D effort (or equivalent investment in acquired technology) is the industry's average, everything else being equal.

The valuation by the stock market of a company's shares strongly supports this point. The efficient theory of the stock market states that the collective judgment of investors and analysts is the best possible evaluation of future earnings, and therefore the value of a company. A study by John Gilman of Amoco Corporation into the relationship of stock market values (number of shares outstanding times share price) of chemical companies versus their respective R&D expense/sales ratios found that the optimum R&D/sales ratio, corresponding to the highest ratio of stock market value/sales, was close to industry average. Also, the stock market attributed a 40 percent premium to the value of companies operating close to the optimum R&D/sales ratio, compared to companies having minimum R&D expenditures. In other words, in this particular case, investing every year 3 to 4 percent of sales in R&D boosted the total company value by 40 percent.

More important, this premium *decreased* gradually for companies with R&D/sales ratios *higher* than optimum and disappeared for R&D expenditures equal to about twice the optimum ratio. Thus, it appears that the stock market, an omniscient Delphic oracle, penalizes equally companies performing too little or too much R&D. The first group suffers from risk of technological obsolescence; the second group is exposed to the high risk of investing too much of their earnings in technologies that may not become operational for a long time.

Market position

Every company has limited resources—for instance, human and financial. Management's role is to allocate these resources where they will contribute the most to corporate objectives. Under certain conditions, it is more effective to shift resources from R&D to marketing.

The PIMS (Profit Impact of Market Share) project was originally started by General Electric Company to determine the relationship between profitability and market share. This project was transferred later to the Strategic Planning Institute with its impressive data base of over 2,000 diverse product and service businesses operated by 200 U.S. and European companies, members of the Institute. In-depth statistical analysis by PIMS researchers has confirmed that profitability increases with market share, everything else being equal. The same analysis has also shown that the optimum level of R&D expense/sales (that is, the level yielding maximum return on investment) also increases with market share. If market share is low (12 percent), the optimum R&D/sales ratio is approximately 1 percent and ROI is 18 percent; if market share is high (26 percent), the optimum R&D/sales ratio is approximately 3 percent and ROI reaches 32 percent.

This means that a company is better able to exploit its R&D efforts if it is already well established in the marketplace. Consequently, if a company has a low market share, an appropriate strategy would be first to allocate its limited resources to marketing and, then, after it has built up market share, to shift gradually some of these resources from marketing to R&D.

Strategic benefits of R&D

Studies of the PIMS data base have revealed the strategic benefits of increasing R&D expenditures to the optimum level. Positive correlation was found between R&D expense and:

- — Sales growth (businesses in rapidly growing markets tend to spend more on R&D in order to maintain or improve market share).
- — Product quality, which, in turn, yields higher return on investment. (IBM, for instance, has consistently maintained top quality in products and services, discontinuing products with low perceived quality, such as the PC Junior or "Peanut.")
- — Rate of introduction of new products, which, in turn, lead to gains in market share and profitability. (Roland Schmitt of General Electric estimated that the new prod-

ucts from the GE R&D Center doubled the profitability of older GE products).

— Gross margins, lagged by new product development time that averaged 3 to 4 years (one percent of sales revenue spent on R&D increased gross margin by 1.1 percent, compared to 0.9 percent for marketing and 0.7 percent for administration and other overhead).

— Return on investment (ROI). For businesses with low or medium investment/revenue ratios (less than 52 percent), increasing the R&D/revenue ratio from less than 0.25 percent to more than 2 percent increased ROI by approximately 33 percent. For investment ratios higher than 52 percent, the corresponding increase in ROI was approximately 20 percent. (Because of the time lag discussed above, leading technology-intensive companies such as General Electric, IBM, Siemens, and Philips maintain almost a constant level of R&D expenditures through the short-term economic cycles to safeguard their ROI levels and also to avoid repeated layoffs and hirings of key technical personnel).

In summary, chief executive officers and their staffs should attempt to determine the optimum amount to invest in technology and what are the most suitable modes for acquisition. The next step is to determine in which technologies to invest and when.

Chapter 4

Where and When to Invest in Technology

MODERN TECHNOLOGY is so highly diversified and fragmented into a multitude of disciplines and application fields that a company with an homogenous line of products, or a strategic business unit in a diversified corporation, should concentrate its limited resources on the "core technologies" of the business, acquiring the "supporting technologies" from outside.

Core technologies

Core technologies are those that are critical for advancing the key performance parameters of the product (or process, system, or service). Sophisticated customers select and acquire a product on the basis of its functional utility, which, in turn, depends on key performance parameters and the performance/cost ratio, or the "figure of merit." For instance, aircraft engines are evaluated according to two key parameters: thrust/weight and fuel efficiency, plus considerations of noise, pollution, reliability, and of course cost. It turns out that the two key parameters depend primarily on the development of new alloys that will be able to operate at high temperatures with high mechanical strength. Thus the metallurgy of high-strength, high-temperature alloys is the foremost core technology of aircraft engine manufacturers, such as United Technologies, General Electric, and Rolls Royce. Other related core technologies are corrosion resistance, fluid flow, heat transfer, and combustion.

To remain competitive, an aircraft engine manufacturer must always operate at the state-of-the-art in these core technologies, and that means investing heavily in R&D activities, with all the necessary facilities and equipment. On the other hand, an aircraft engine manufacturer need not be expert in the supporting technologies—for example, noise and pollution measurement. The appropriate instrumentation may be acquired from suppliers, such as companies or independent laboratories specializing in these fields.

Limited life of core technologies

It is not difficult for a company's scientists and engineers to identify the core technologies and recommend to management appropriate levels of investment in manpower and facilities. A major problem, however, arises from the fact that in technology-intensive industries core technologies have *limited life*. For instance, mechanical typewriters were displaced first by electrical typewriters, then by word processors, which are now being replaced by personal computers. *Future core technologies*, then, are those technologies that have the *potential of displacing* the present core technologies.

Technology assessment and technology forecasting are useful to establish the relative merits and timing of emerging and developing new technologies. To illustrate this point, consider a simple function: shaving. Some time ago people used razors with removable blades. The core technologies of the razor and blade manufacturers were the metallurgy of the blade steel, the automated manufacture of the blades, and quality control. As people shifted to electric razors, blade metallurgy and manufacture remained core technologies, but a new technology was added: the design and production of miniature electric motors with low energy consumption. Batteries of low weight and high-storage density were required, but this supporting technology was usually procured from other strategic business units or outside suppliers.

What are the future core technologies in this instance? It appears that since blades, electric motors, and batteries are components based on relatively mature technologies, no revolutionary improvements in the performance parameters of electric razors are to be expected. On the other hand, depilatory creams that will remove hair through the application of safe chemical or biological agents appear to have promise. If successful, these creams will replace razors within a *diffusion period*, which may take three to 20 years. The new core technologies will be chemical, pharmaceutical, and biological and will have nothing in common with the present core technologies.

Thus, two key strategic challenges for management are: How do we identify future core technologies and when do we switch? To answer these questions, we must look at the technology life cycle.

The technology life-cycle

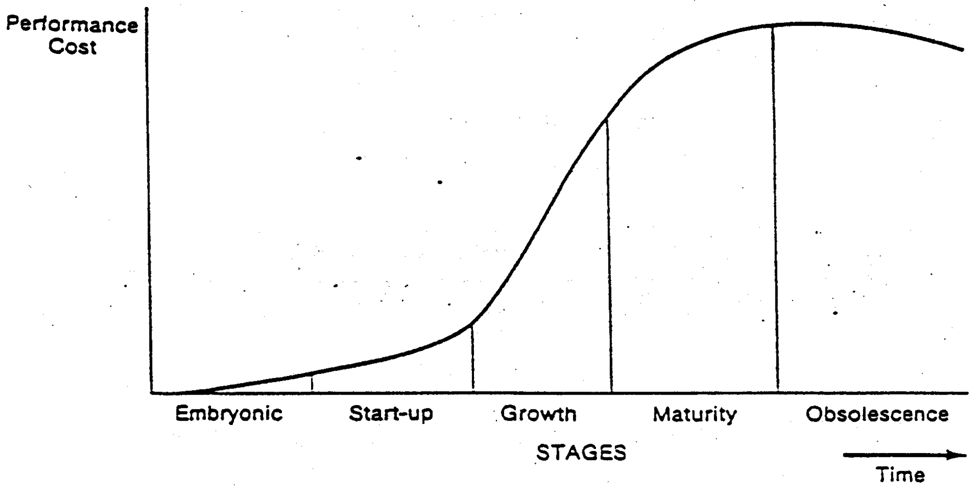
Technologies, just as products, go through life cycles and are replaced sooner or later by superior technologies. Figure 3 shows a typical technology life-cycle S-shaped curve. The vertical axis measure is the "figure of merit," that is, a measure of the relative value of the technology to the user. Such "figure of merit" could be performance/cost for computers, efficiency for steam turbines, thrust/weight for military aircraft engines, or yield for a chemical process.

We can distinguish several stages in the S-curve using as an example the evolution of superconducting materials in liquid helium at the General Electric Company and its spinoff firm Intermagnetics General Corporation. Superconductivity, the ability of certain alloys and compounds to carry electricity without losses, was discovered by the Dutch physicist Heike Kamerlingh Owens in 1911. This phenomenon remained a laboratory curiosity for 40 years, because it appeared at very low temperatures, which could only be obtained by liquifying helium, a rare gas, at −269°C (4° Kelvin).

By 1960 the GE R&D Center decided to perform basic research and some development (note the 50-year time lag between scientific discovery and the beginning of commercial R&D). Let's look at the various stages of technology development in terms of Figure 3.

1. **Embryonic.** Basic research was carried out to understand the physical theory underlying the phenomenon that led to a Nobel prize for GE's researcher

Figure 3 The Technology Life Cycle



Ivar Giavaer in 1973. Concurrently, small samples of various superconducting alloys were manufactured and tested.

2. **Start up.** Possible applications were investigated and the world's first 100 kilogauss (10 Tesla) superconducting magnet was built by GE and delivered to Bell Laboratories. However, the market was too small and the risk too high, so GE, rather than going into the business directly, encouraged members of the research team to set up their own new venture, Intermagnetics General, in 1965. This company grew slowly because the market for such magnets was limited to research laboratories.

3. **Growth.** In 1978, a new modality for medical diagnostics, magnetic resonance imaging (MRI), was developed by General Electric and its competitors. This required the construction of large superconducting magnets in which patients could be examined, and the market suddenly increased from tens of millions to billions of dollars. Intermagnetics General has now $12 million/year of sales, and GE is now producing its own superconducting magnets.

4. **Maturity.** Business for helium-refrigerated superconductors is still booming, but the recent discovery of IBM scientists and others of materials that operate at liquid nitrogen (−196°C, 77° Kelvin), and are therefore much easier to refrigerate, has shifted all R&D efforts to these new materials.

5. **Obsolescence.** As soon as these new superconducting materials can be mass-manufactured, they will replace present superconducting materials, which will then become technologically obsolete. (According to some authorities, this may take five to ten years, despite intense worldwide efforts.)

Evaluating emerging versus mature technologies

A corporation must be on the lookout for emerging technologies (normally in the start-up stage, since those in the embryonic stage are too difficult to identify) that may replace its core technologies. At the same time, it is necessary to detect early warning signs that a technology is achieving maturity and, therefore, its benefit/cost curve is flattening out. According to Richard Foster of McKinsey some of these signs are:

- Loss of creativity and productivity of R&D personnel who would prefer to work on more exciting and potentially rewarding technologies.
- The gradual shift from product innovation to process innovation; that is, from improving the product characteristics to improving the process for purposes of cost reduction.
- The appearance in the market of new competitors with more advanced technologies.

Equivalent efforts (in terms of people and dollars) to advance competing technologies, will yield much higher improvements in cost/performance for the emerging technology than for the mature one. This identification is done by the process of technology monitoring and forecasting, where one attempts to project and compare the S-curves of competing technologies.

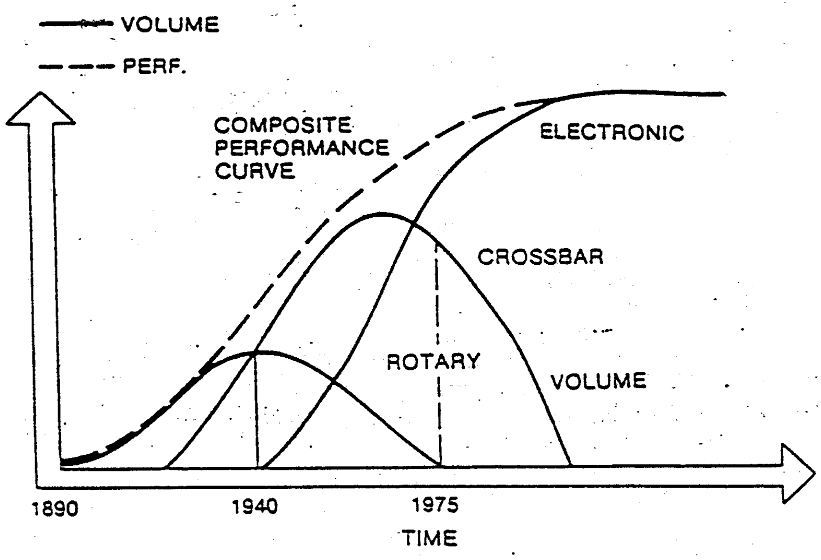
Rather than setting up a specialized group for this purpose, it is simpler and much less expensive to rely on "technological gatekeepers" within the company. These are scientists or engineers who, regardless of their specific job assignments, keep up with the progress of the state-of-the-art of the technologies that interest them. They do this, often on their own time, by reading technical magazines and patents, by going to technical meetings, and especially by maintaining an informal network of contacts with peers in universities, laboratories, and industry and professional societies. Management should assist and reward these technological gatekeepers and encourage their co-workers to make use of their expertise. In fact, some companies issue technical directories where these gatekeeper persons are listed according to the fields of technical expertise.

Switching technologies

Switching from a mature or obsolescent technology to a new one in the growth stage is vital for advancing the business and maintaining competitive advantage. Consider, as an example, the case of telephone switching systems (Figure 4). Originally, telephone switching (that is, connecting the caller to the called person) was done manually by telephone operators. The rate of growth of subscribers and their calls was so fast that at the end of the last century, it was forecasted that by 1920, the entire female population of the nation would be working at the manual telephone switchboards. The Strowger electromechanical rotary (step-by-step) system was introduced in 1892 and performed yeoman service for many, many years. However, it was noisy, used excessive space and power, required continuous maintenance, and was not suited for data transmission. In the thirties, Ericsson of Sweden and the Bell System developed a superior (in terms of performance/cost) electromechanical system, the Crossbar, which is still manufactured today in many countries.

The application of computers and semiconductors led to the design of all-electronic switching systems, with highly superior performance (in terms of reliability and additional capabilities for data and video). As can be seen from Figure 4, the three technologies form an S-curve of the type previously discussed (Figure 3) that, at the same time, shows both the increase in performance/cost and the increase in

Figure 4 Technological Evolution of Telephone Switching Systems



volume of traffic. Thus the telephone industry, in contrast to others (such as steel or railroad transportation), has continued to grow despite its maturity and has avoided technological obsolescence. In fact the merger now in progress of computers and communications technologies may bring about a third discontinuity that will continue the growth of the industry and delay further obsolescence.

While switching to new superior technologies is good for the industry, it may not be advantageous for the dominant supplier—in this case, the Bell System (AT&T). Because of its monopolistic position and the heavy investment in installed switching systems, which were only partially depreciated, Bell was slow in switching from electromechanical to electronic technology, particularly in private automatic branch exchanges (PABX). This discontinuity was instead exploited strategically by Northern Telecom, the leading Canadian manufacturer of telephone equipment. By switching to the electronic technology before Bell, Northern Telecom was able to invade the U.S. market from the much smaller Canadian market which is one-tenth that of the United States. In the early sixties, Western Electric (now AT&T Technologies, the manufacturing arm of the Bell System) provided at least 90 percent of the installed U.S. PABX equipment. Now, it makes only about 30 percent and Northern Telecom 40 percent. Northern Telecom has used the Canadian and U.S. markets as springboards to conquer the world. It developed digital switching systems ahead of Bell and in fact it is now the world's leading producer of such systems, with 80 percent exported. Thus, switching to the right technology at the right time has given Northern Telecom a sustainable competitive advantage in relation to dominant suppliers in the United States, Europe, and Japan.

When to switch

As we have seen, timing is critical. A premature switch from an established process or a product well-accepted in the marketplace that produces substantial earnings and positive cash flow may "kill the goose that lays the golden eggs." Such a premature switch may imply the write-off of production facilities not yet fully depreciated and the assumption of heavy front-end expenses for retaining production, maintenance, and sales personnel. On the other hand, "hanging on" to an obsolete product or process may lead to a significant loss in market share to more aggressive competitors, with consequent sharp declines in profitability, and may even jeopardize the future of the entire corporation.

An appropriate strategy for a technological and market leader, such as IBM, would be to develop the new technologies and keep them "on the shelf," in order to be ready to switch at the most opportune time. Such optimum timing would be determined by external forces such as the changing needs of customers and competitive actions, and by internal considerations, such as profitability and cash flow.

In practice, studies have shown that most companies tend to switch *too late* from an obsolescent to more promising technology. A striking example is given by the fate of two major producers of mechanical cash registers: Burroughs and NCR. Both companies recognized early the importance of an emerging technology—electronic computers—and, in fact, both tried for a while to compete with IBM in the electronic data processing business. Burroughs switched early (1971) from electro-mechanical to electronic cash registers. In the same year NCR made the decision to stick to electro-mechanical technology and to invest heavily in improving the existing plant. The results of this wrong technological decision were traumatic for NCR. The market share of electro-mechanical cash registers declined from 90 percent in 1972 to 10 percent in 1976. NCR was forced to write-off $140 million of "new" but technologically obsolete equipment. The CEO was fired, 80 percent of the top executives lost or changed their jobs, 20,000 workers were let go, and stock fell in price from $45 to $14.

In contrast to NCR, the Olivetti Company switched at the right time from mechanical to electronic typewriters. Its largest plant in Ivrea, Italy, was closed down for six months and completely rebuilt. Although in Italy workers cannot be let go, Olivetti obtained the agreement of the very strong local unions to temporary lay-offs and reduced-time work. During these six months, most of the workers were retrained, and some of the older ones were retired early. Olivetti thus maintained its worldwide leadership in typewriters and word processing, while developing its personal computer business.

Clearly, switching to a new technology may be risky, but it may be even riskier not to switch in time.

Chapter 5

Evaluating a Firm's Technological Assets

By investing in the present and future core technologies, a company builds up its technological assets. However, because technologies evolve rapidly and a firm's strategy and product scope change, it is necessary to assess regularly the value of these technological assets *to the company*. This evaluation is best done in two steps:

First, by developing the technology/product matrix, and

Second, by assessing the competitive position of the firm in the key core technologies.

The product/technology matrix

For each homogenous product line, it is first necessary to identify the core technologies that the firm needs to master in order to maintain and improve its competitive position, and the support technologies that can be obtained from suppliers or other outside sources. For instance, let us look at the electric fork-lift trucks product line of a hypothetical manufacturer of small carts and trucks. Among the present core technologies are: lead acid batteries to store energy, static power converters and motors to convert electric power into mechanical power, control systems to direct movements of the truck and the fork lift, and reinforced plastics to reduce the weight of the body of the trucks. Future core technologies might include: new energy storage systems, robotics (to replace human-controlled trucks), and computerized automatic part storage and retrieval systems. Supporting technologies would include distance sensors to detect animate or inanimate obstacles and automatic emergency braking systems.

The same exercise would be repeated for other company product lines—for instance, gas-powered fork-lift trucks, wire-guided electric transporters, and golf carts. The result would be the product technology matrix of Figure 5, indicating which products utilize which technologies and how important these technologies are for each product, according to the scale: High, Medium, Low, and None. The evaluation of the importance of the technology should be made for the time period of the product line plan or of the company's strategic plan, usually for a minimum of five years. As shown in Figure 5, a direct or weighted average can be made to determine the importance of the technology for the company as a whole. The weighing factors could include the strategic importance of the product line, its market position, and the leverage that technology may have in improving the competitiveness of the line.

The technology importance/competitive position matrix

After having analyzed the importance of all core technologies for the company, the competitive position of the company should be evaluated for each technology. This assessment is best done by knowledgeable company engineers and the previously discussed "technological gatekeepers," with the help of outside consultants to avoid the NIH ("Not Invented Here") syndrome. The results can be plotted in the matrix of Figure 6 that shows the position of each technology in relation to the importance for the company (according to the previously used High, Medium, and Low scale) and the company's competitive position (according to the Lead, Equal, and Follow scale).

Positioning the core technologies

The aggregate position of the core technologies in the matrix making up Figure 6 shows the value of the technological assets of the company. Obviously, a company with most technologies in the upper left-hand corner (high-lead) is much better off than one with technologies scattered all over the matrix or, worse, bunched towards the lower right-hand corner (low-follow). More important, the matrix indicates what strategies could be applied to each technology. Here are some examples:

T1 and T6. The company leads in these technologies, which have high importance for the business. The company should continue to invest in R&D for these technologies, to maintain and improve the company's competitive position in the marketplace.

T4. The technology is of high importance for the company, but the competitive position is weak. Depending on the time window available for catching up, the company should either initiate a major R&D program or acquire the technology in order to follow the direction of the arrow from "follow" to "equal." If this is not

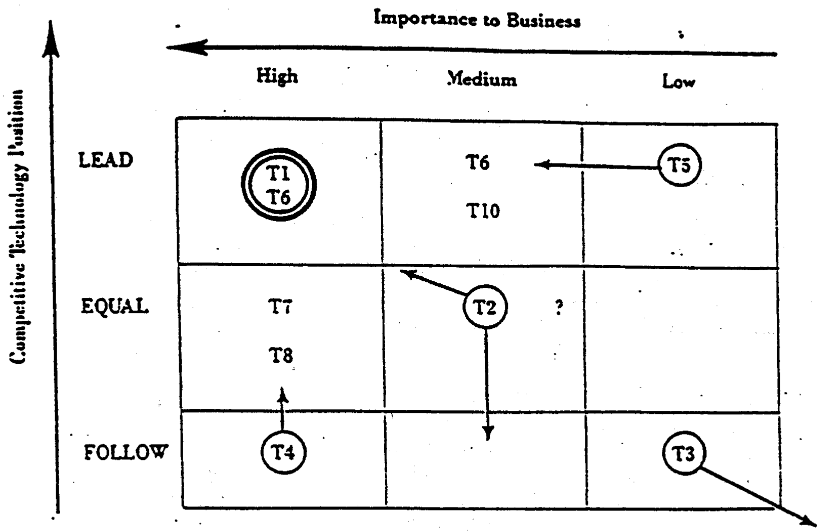
Figure 5 The Product/Technology Matrix

Importance of Technology / Products

Technologies	P1	P2	P3	• •	PN		Company
T1	H	L	M		M	→	M
T2	O	L	M		H	→	M
T3	H	M	H		O	→	H
•							
•							
TN	L	M	O		L	→	L

Importance of Technology: H = High, M = Medium, L = Low
O = None

Figure 6 The Technology Importance/Competitiveness Matrix



possible, the corresponding product lines should be harvested since they will gradually lose their competitive position.

T5. The company leads in this technology, but the importance to the business is low. There are two possible strategies: Either it can incorporate this technology into existing or new products of higher importance to the company, following the direction of the arrow from "low" to "medium"; or it can sell the technology by licensing it to other companies for which it has higher importance, or start a joint venture to leverage the strengths of the partner.

T3. The company has a weak position in this technology, which has low importance. The appropriate strategy is to stop all investment in this area (except for some monitoring) and, if possible, sell the technology—for instance, to a developing country.

T2. The value of this technology to the company is not clear. The company could try to shift the position towards the high-lead corner or else could exploit it in a limited market niche, although that niche may eventually disappear.

Chapter 6

Technological Strategies

As we have seen in Chapter II, a company, to gain a competitive advantage from its technological assets, must incorporate the core technologies into the company's products, systems, services, and processes. In general, the payoff will be considerably higher than the gains to the company from selling its technology outright or through a joint venture, but the risk may also be higher.

It is very important to note at this point that a sophisticated customer purchases new technology-intensive products not because they embody the latest technological advances but rather because they provide improved or new functional utilities—that is, customer benefits. The customer is concerned only with the functions performed and their benefit/cost ratio, not with the underlying technology ("what" the product does, not "how" it does it). Thus, the buyer's role is to specify the desired functions, and the supplier's role is to select the *most appropriate technology* (not necessarily the most advanced) that will efficiently perform these functions. Professor Eric von Hippel of MIT has shown that, in general, the higher the value to the user (customer) of a technological innovation, the higher the returns to the innovator (the supplier).

Technology as the basis for competitive advantage

Looking at technology as the basis for competitive advantage, it can:

- Improve the customer's benefit/cost ratio by providing new or improved products, systems, and services that are superior to those available in the marketplace (from the company and its competitors).
- Offer products and services with the same benefit/cost ratio (for the customer) but lower total cost to the company.

In the first case (innovative products), the firm may gain competitive advantage from the higher performance of the product to:

- Create a totally new market, which had not been targeted by competitors. (For instance, Apple created the personal computer market, which had been ignored by Hewlett-Packard, IBM, and DEC.)
- Catch up with and overtake competitors that created the new market. (IBM developed the PC several

years after Apple, but it now has a higher market share.)

— Develop a replacement market for products of mature technology. (General Motors diesel-electric locomotives replaced within 22 years 60 percent of all steam locomotives.)
— Establish a limited market niche that can be protected from competition through a strategy of differentiation. (Cray Research is now the world leader in supercomputers.)

In the second case (lower total cost of products), a firm may decide to change the technology embodied in a product for various reasons. Using the telephone as an example, developments

— Lowered production costs by, for example, replacing manual welding with robots.
— Increased reliability or maintainability through, for instance, the replacement of rotary Strowger systems by crossbars in telephone private branch exchanges.
— Improved efficiency, with, for example, digital voice transmission replacing analog transmission in local telephone loops, thus carrying more conversations in a single circuit.

The customer sees no change in the functions performed but benefits in terms of reduced price and higher quality of service. The firm benefits from higher margins due to the lower production and maintenance costs.

The various options described above lead to four basic technological strategies or, more precisely, four business strategies where technology plays a dominant role:

1. First to market (new or replacement)
2. Fast follower . . . and overtaker
3. Cost minimization
4. Market niche.

Let's look at these four strategies and compare them in terms of the required investment level, risk, and impact on personnel selection and organization.

First-to-market strategy. The first-to-market strategy is offensive, with potential high rewards but also high risk. It is often used by new entrepreneurial high-tech ventures and by more progressive established firms, such as 3M and GE. A new technology, or a new synergistic combination of existing technologies, is applied to introduce to market a product embodying a radical technological innovation, which will yield high functional utility to the user. If this competitive advantage can be sustained—for instance, through solid patents and proprietary knowhow—the company enjoys a temporary monopoly that can be exploited to optimize market volume and profits. Polaroid's instant photography, based on patents that have kept Kodak and all other competitors out, is a classic example of such a strategy.

In other cases, it may not be possible (or even desirable, in view of the antitrust legislation) to keep all competitors out. However, a company may maintain a leading market share for a long time, thanks to an initial technological leadership that was converted into market leadership. For instance, General Motors first developed diesel-electric locomotives in 1935 and now, 54 years later, still commands a market share of 60 percent, while GE, a latecomer to this business, has about 30 percent. Similarly, Motorola, the leader in mobile radio communications, still has about 60 percent of the market it developed about 40 years ago.

The initial competitive advantage in this first-to-market strategy derives from the fact, already noted, that original technology, properly protected, gives to a firm a temporary monopoly that is legally enforceable. A monopolist thus can control the price charged, which, in turn, determines the volume of goods sold, according to the price elasticity relationship.

What is the optimum price for this? There are two basic pricing strategies:

Pricing for maximum profit. Economic theory shows that a monopolist can maximize profits by choosing the optimum price/volume combination. By setting a high price, the profit per unit sold will be high, but the number of units sold will be low and the revenue = price × units will also be low. By setting a low price, the number of units sold will be high, but the profit per unit will be low and therefore the revenue also low. Between these two extremes there is a price that maximizes the relationship

$$\text{profit} = \text{units} \times (\text{price-cost}),$$

keeping in mind that cost decreases with volume.

Some firms utilize this approach in order to recoup in a relatively short time their heavy investment for developing the technology and launching the new product. They then attempt to keep the price constant in order to increase profits, as costs decrease with volume according to the learning curve. This strategy is shown graphically by the left hand portion (A) of the price curve in the upper half of Figure 7.

Profits increase with time during the life of the product. IBM was utilizing this strategy when it developed a new magnetic disk drive memory in 1968. General Electric, at that time in the computer business, had tried unsuccessfully to develop a similar product. To continue to sell its computer systems, GE was forced to buy IBM's disk drives in very large quantities. IBM could not legally refuse to sell to its competitor, but it refused to offer quantity discounts and thus maximized profit.

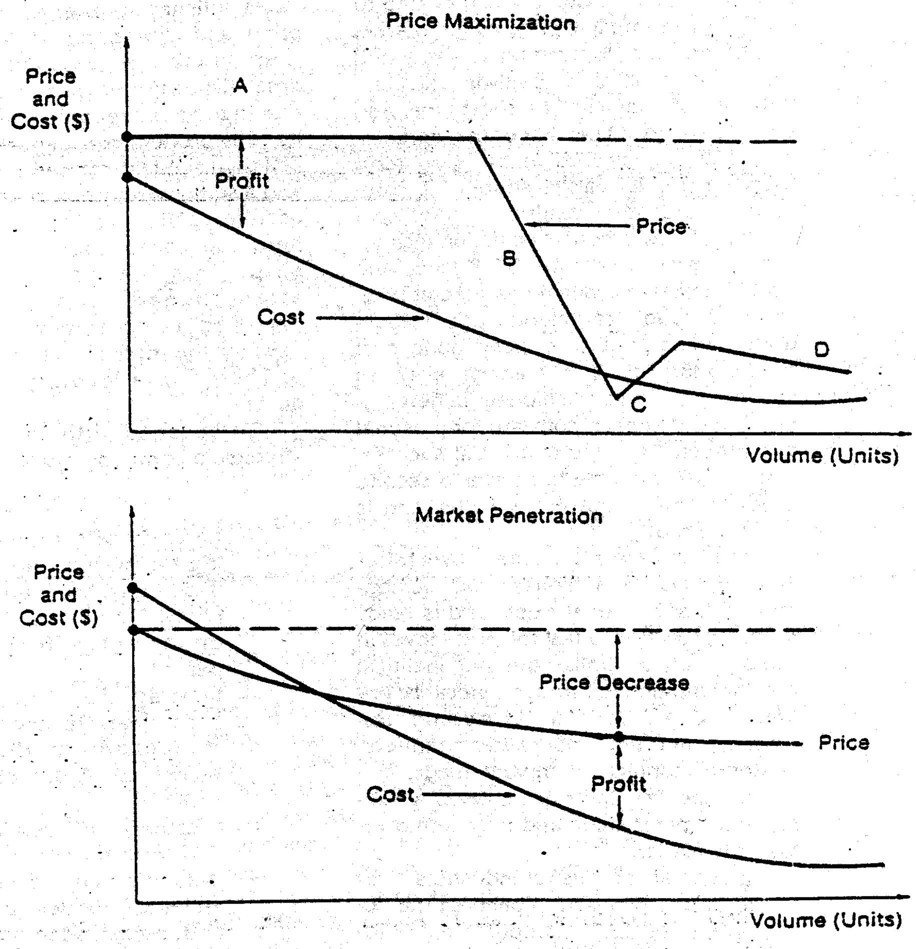
The problem with this "high-price" strategy is that it creates an umbrella under which competitors may move even if their profits are lower than the leader's. This was the case of the "seven dwarfs" which competed with IBM, producer of IBM compatible components, such as central processors (Amdahl) and disk drives. These competitors either were able to get around IBM's patents and knowhow or else were tolerated by IBM because of the danger of being sued under the antitrust laws. Eventually, as more and more suppliers crowded into the limited market (no less than 30 for disk drives), there was overcapacity in the industry and prices collapsed, often yielding negative profits for the majority of competitors (B curve in Figure 7). In such situations a shakeout ensues (C curve), the fittest survive, and now the price curve follows the cost curve with low profits as shown by curve D.

Pricing for market penetration. To forestall this danger, the *market penetration* strategy is adopted by many progressive companies. As shown by the lower half of Figure 7, initial price is set at a level that will encourage penetration by the early adopters. Then the price is decreased steadily according to the learning curve to spur sales growth. Thus, the lower profits are traded for faster market penetration that, in turn, will ensure sustainable market leadership by the firm.

Returning to the introduction of diesel-electric locomotives by General Motors, their price was initially set at ten percent *below* the price of steam locomotives. This combination of much higher performance and lower cost overcame the resistance of the conservative management of most American railroads, which were traditionally tied to their major customers, the coal mining companies.

As General Motors' costs came down on the learning curve, GM reduced its prices by about half the cost savings (as shown in the lower half of Figure 7). This, of course, increased the speed of market penetration, which, in turn, yielded con-

Figure 7 Profit Maximization and Market Penetration Pricing Strategies



tinuously lower production costs and prices. When diesel-electric locomotives had achieved 20 to 30 percent market penetration, the three leading producers of steam locomotives—ALCO, Baldwin, and Lima—decided to switch to diesel. Too late! Their production costs were probably equal to the initial production costs of General Motors, but they had to charge the same low price as the market leader, and they lost money on every unit sold. As a result, ALCO, Baldwin, and Lima went out of business in a short time, and GM still enjoys 60 percent of the market.

Thus, to succeed *in the long term* with the *first-to-market* strategy, a company should either continue to produce a stream of new products based on technological innovations (like GE Plastics and GE Silicones) or maintain its market leadership through continuous price reductions, which in turn, depend upon cost reductions. This is not always easy, as shown by Visicalc, the pioneer in developing "spread sheets" software for personal computers. After the fast initial success, Visicalc was not able to develop a second product, was overtaken by Lotus, and is now bankrupt.

Fast follower . . . and overtaker strategy. Once a pioneer has demonstrated that a market exists and is ready for an innovation, a fast follower moves in rapidly with a similar but not identical product developed through *innovative imitation.* Capitalizing on its existing production facilities, marketing channels, customer contacts, company image, and so on, the fast follower achieves a substantial market share and may even overtake the leader.

Electrical and Musical Industries (EMI) in the United Kingdom pioneered the development of CAT (Computer Axial Tomography) scanners for medical diagnostics. This was a major innovation, of great humanitarian value, recognized by a Nobel prize granted to a senior EMI researcher. General Electric, the major world producer of conventional X-Ray equipment, correctly assessed that the EMI CAT scanner was a major threat to its market leadership. Therefore, GE started a crash program in its R&D center to develop a similar scanner, without infringing on EMI's patents. This program was highly successful, and soon GE, capitalizing on its established market position with hospitals and clinics, had a leading market share in this new segment. In the meantime, EMI suffered heavy start-up losses due to the poor reliability and serviceability of its product and a shortage of capital. EMI then sued GE for patent infringement, and a settlement was reached whereby GE acquired EMI's medical electronics business and consolidated its world leadership. This leadership was further strengthened when recently GE "swapped" its consumer electronics business for the medical electronics business of Thomson, a leading European producer.

To succeed with the fast-follower strategy, a company must:

— Carefully select the optimum timing for introducing the product—if too early, the market may not be ready; if too late, the "window of opportunity" may have disappeared.
— Leverage its strengths in other areas than technology, such as manufacturing, distribution, or service (as GE did for the U.S. market).
— Creatively differentiate its imitation from that of the pioneer, because a strictly "me too," undifferentiated product has little chance of success in the marketplace (as GE did through its well-respected trademark, extended warranties, application engineering, customer training, and endorsement by leading doctors and clinics).

To illustrate further these last two points, let us compare the reactions to the threat presented by Apple to two leading computer manufacturers: IBM and Digital Equipment (DEC). Both IBM and DEC were surprised and shocked by Apple's success, and both started "crash" programs to follow Apple's lead. Their timing was approximately the same, and both companies had the required manufacturing capabilities. However, IBM was able to differentiate its PC on the basis of company image and reputation, which attracted software from many sources. DEC, on the other hand, developed not one but three different PCs, each designed by a different team, that were looked upon by the market as "three more PC models." Eventually the Rainbow emerged as the winner of the three, but it never achieved the sales volume of Apple's and IBM's PCs; DEC had dissipated its limited resources over three systems and was unable to leverage its strengths in the marketplace, such as the loyalty of its minicomputer (VAX) computer base.

Cost minimization strategy. The cost-minimization strategy is particularly effective for mass-produced goods, with standard features, where significant economies of scale can be realized through process innovation. Using this strategy, the Japanese, and then other Pacific Rim countries, succeeded in wiping out much of the U.S. consumer electronics industry that, in its heyday, had $8 billion in sales and employed 80,000 people. On the other hand, the recent sale of GE's $3 billion television and audio strategic business unit to Thomson must have been based on the conclusion that such a strategy is not appropriate for a high value-added company such as GE.

Once the diffusion of a technological innovation is well under way, the functional differences between products of various brands become less important, personal selling is replaced by mass marketing, and price becomes the dominant factor in the customer's decision to buy. At this point, a company can standardize the product and minimize production costs through automation, riding down the learning curve as volume increases. In parallel, marketing and distribution costs are reduced—for instance, by telemarketing and discount stores.

The company thus strives to become the lowest cost producer and, therefore, the price leader. By gradually reducing the price in parallel with the learning curve costs, the company forces less efficient competitors to withdraw, the market stabilizes, and the company increases further its market share. The Japanese were masters in implementing this strategy. Because their domestic market was closed to foreign imports, they were able to practice a two-tier pricing: (1) full price, based on first-shift costs with full overhead, for the domestic market, and (2) marginal price, based on the costs of the highly automated second and third shifts, for the foreign market. Such a forward pricing, in anticipation of the learning curve, not only "shakes out" the less efficient competitors but, more importantly, discourages from entry the more powerful potential competitors.

This strategy was successfully appliec in the '50s and '60s by Giorgio Zanussi, an Italian manufacturer of refrigerators, washing machines, and dishwashers. Af ter the end of the war in Europe, suc appliances were still considered luxur items and were taxed as such. The leadin North European producers, such as Sie mens, AEG, Philips and Electrolux offere very high quality but expensive items t what was a limited market. When Italy' economy boomed, Zanussi realized th there was an untapped market for smalle size, less fancy appliances at an affor able cost. He designed his line of appl ances to minimize total cost (material labor, distribution, and the like) by pr ducing appliances of minimum accept ble performance but good quality. He w able to offer his line at about half the price of the established manufacturers and conquered first in Italy, then Southern Europe and the Mediterranean basin. Unfortunately, he died in an accident, and the company lost its cost leadership through repeated strikes and ill-fated attempts to diversify—for instance, in home solar heating systems. As a result, the Zanussi Company was recently acquired by Electrolux.

To succeed with this strategy, a company must continuously reduce its *total costs* (not just manufacturing costs) while maintaining an acceptable level of *quality*. It is a dangerous illusion to believe that, in the medium or long term, customers are willing to trade lower prices for quality. Detroit found this out the hard way. After the oil crisis car companies attempted to develop compacts and subcompacts that would compete with Europeans and Japanese models. Detroit's quality (as measured by the number of defects in a new car on the dealer's lot) was one-half to one-third that of leading foreign competitors, such as Toyota and Volkswagen (VW). Therefore, American consumers were willing to pay premiums of from $1,000 to $1,500 (equal to 15 to 20 percent of the cost of the car) in order to obtain the quality they demanded, and to wait several months for deliveries from Japan, while the unsold Detroit cars filled dealers' lots.

Market-niche strategy. The market-niche strategy is favored by new, high-tech ventures that are looking for "a place in the sun" in competition with established dominant suppliers. Digital, Wang, and Control Data all adopted this strategy in their initial growth stages, in order to compete with IBM.

To succeed, the market niche must be carefully selected-then adhered to. If the niche is too small, the opportunity for growth is limited, and the saturation point will be reached in a relatively short time. Thus, Control Data, in order to continue to develop, was forced to abandon its original profitable but limited niche and compete head on with IBM in data processing, with serious declines in profitability.

If the niche is too large, it is no longer a niche, and is an attractive target of more powerful competitors that, up to that time, have disdained the limited and apparently unprofitable (for them) market niche. For instance, DEC established itself with the PDP and VAX computers in the laboratory and university scientific computing and data acquisition market, a market IBM had avoided because of its limited initial size and especially because it demanded too much application engineering effort and too many nonstandard components. However, this market (and consequently DEC) grew faster than the conventional business data processing market. Consequently, last year IBM, facing a decline in revenues and profits, announced that it intended to attack it with a new product line.

Another danger of the market-niche strategy is that it may be wiped out by the progress of technology and the resulting merger of previously separate industries, such as computer and communications. For instance, Wang had carved for itself an excellent position in the word-processing market niche. The rapid progress in mini- and micro-computer technology has eliminated the distinction between word-processors and personal computers, and the latter are now preferred for office work.

Cray Research has implemented very successfully this strategy and remains the uncontested leader in the limited, but highly profitable, market niche of supercomputers. The company's mission is still the same as stated by its founder, Seymour Cray, in 1972: "to design and build a larger, more powerful computer than anyone now has." Because of that mission, Cray decided to concentrate on a market niche so small (estimated at 80 users worldwide in 1976 and 400 in 1982) and so demanding that competition could not easily break into it. This niche, however, represents a fast-growing market from $260 million in 1984 to over $1 billion by 1990. By 1983 Cray Research had installed 88 computers around the world, controlled nearly two-thirds of the market, and had revenues of $170 million, net income of $26 million (15.4 percent of revenues), and 1550 highly specialized employees. How did Cray do it?

Since the market niche is so small, Cray Research has identified practically all its potential customers and can "sell" them individually "by showing and demonstrating the product, not by making claims in magazines to accept at face value." In fact, Cray's advertising budget is exactly *zero*!

But Cray's leadership is being threatened. On the domestic scene, Control Data (through its subsidiary ETA Systems) and IBM, both of which had previously built supercomputers and abandoned the market as too small and unprofitable, are trying to get back in the field. On the international scene, the Japanese have launched, with government and private funds, massive research in the fifth-generation computer, to follow and overtake Cray Research.

To succeed in this strategy, a company should be *very selective* in accepting orders that would entail too many "specials," or excessive and expensive efforts in development and design engineering to meet the unique specifications of a customer. The secret is to have one or more basic designs, which can be easily and rapidly adapted to the diverse requirements of prospective customers.

Sizing up the four strategies

Comparing now the four basic strategies described above, the first-to-market one is definitely the one that requires the highest R&D expense and entails the highest risk of failure.

The market-niche strategy is less expensive and less risky, but, as we have seen, may be only valid for a limited period if the company continues to grow or if the evolution of technology removes the limits of the niche.

The fast-follower-and-overtaker strategy, while less risky than the first-to-market strategy, may be quite expensive, because of the need of implementing, within the short "window" available for entry, a "crash" R&D and production facility program as well as getting around the patents of the leader.

Finally, the cost-minimization strategy, while not generally requiring major R&D efforts, will entail major investment in plant and equipment, which may become a "white elephant" if there are major reductions in market demand, changes in customer preference, or most dangerous of all changes in the dominant technology. For instance, as we have seen, NCR had to write off its new production facilities because electronic technology had made its mechanical cash registers hopelessly obsolete.

Impact on technical personnel and organization

Company management must also consider the impact of the four strategies on the selection and organization of technical personnel, since people (and not technology alone) are the major resource and the ultimate key to success of a corporation.

To implement the first-to-market strategy, the company needs to recruit a team of creative and entrepreneurial technical people, willing to assume high personal and business risks in order to advance the technology beyond the state of the art and achieve a radical innovation. The organization should be organic, flexible, informal, and entrepreneurial—one that rewards creativity and success and not unduly penalizes failure. The organization should be measured for its effectiveness (doing the right things) rather than its efficiency (doing things right). Many young high-tech entrepreneurial companies of Route 128 and Silicon Valley have followed this pattern successfully.

For the fast-follower-and-overtaker strategy, a company needs a team of flexible, responsive development engineers who can practice innovative imitation within well-defined functional specifications. Creative, entrepreneurial researchers are not suited for this task since they will prefer to conceive a new solution to the problem, entailing a high risk and an extensive time period for implementation. In fact, such creative researchers would probably reject imitation as beneath their professional standing. The organization should be flexible, ready to move fast towards a well-established goal, and able to meet deadlines and cost objectives. There should be a balance of effectiveness and efficiency, and rewards for meeting both technical specifications and schedules.

The concepts of "skunk works" or "internal venturing"—that is, the setting up within the company of independent groups of people, with specific goals but maximum autonomy—can be very fruitful. With this approach IBM developed its highly successful PC in less than one year (rather than three years, which would have been the case if the development had taken place in IBM's established divisions), and the first year's actual orders were three times the forecasted amount. Similarly, Data General, in its skunk works, developed in less than a year a computer that overtook DEC's well-established competitive offering.

For the cost-minimization strategy, technical personnel should concentrate on *process* rather than product improvement. The goal is to freeze as soon as possible the design, avoid costly improvements or changes in the specifications, and ride down the learning curve by continuous process improvements, such as automation, material substitutions, and inventory reductions. Therefore, an elite team of process and manufacturing engineers is needed, rather than R&D people who would prefer to improve the product on the basis of new technological capabilities or changing market demands. Such product changes would greatly reduce the benefits of the learning curve.

Also needed are value analysts and financial auditors dedicated to cost reductions in all possible areas.

The organization should be hierarchic and bureaucratic with rigid procedures and detailed measurement systems. Originality is not welcome, except within the narrow scope of improvements for cost reductions; efficiency is rewarded more than effectiveness. Such an organization is typical of the assembly lines of many American factories, starting with automobile and steel manufacturers.

Finally, the market-niche strategy requires a team of application and custom engineers, and advanced product designers, who can customize the basic product designs to meet the customer specifications with a minimum of hardware and software changes.

The organization should be flexible but controlled, should encourage close coupling with customers and free communication channels internally and externally, and reward originality within the pre-established narrow scope. This type of organization is found in many software houses and consulting companies, particularly in their early stages. As noted, DEC and Control Data started with this type of organization.

The fact that personnel and organizational requirements of the four strategies are quite different leads to two very important consequences, which limit the strategic freedom of action of the company or independent business unit:

1. It is difficult and confusing to have different technological strategies to coexist in the same organization. For instance, the first-to-market strategy requires a creative and organic climate, while the cost-minimization strategy requires a hierarchic and bureaucratic climate. This would lead to a clash of the two cultures and, if the bureaucrats win, the departure of the creative people. If the creative people win, it will be difficult, if not impossible, to minimize cost by enforcing design freezes and rigid control procedures.

2. If the company decides to switch from one strategy to another, the impact on key personnel may be traumatic. Consider, for instance, the impact of moving from a first-to-market to a fast-follower strategy. The best technical people will leave because they are not interested in imitative innovation or reverse engineering tasks.

The Olivetti Company, under the leadership of Adriano Olivetti, the son of the founder, followed the first-to-market strategy on typewriters with success. Since, as we have seen above, different strategies cannot coexist, it adopted the same strategy for personal computers and developed, ahead of IBM, a technically and functionally excellent product that achieved some success in the European market. However, after IBM developed its PC, this became the *de facto* standard, and most Olivetti users in Europe and elsewhere switched to IBM because the majority of the software was compatible with IBM and not with Olivetti.

After Adriano Olivetti's death, the Olivetti family lost control, and the Italian banks named Carlo De Benedetti CEO. De Benedetti realized the futility of trying to beat IBM in the world market, and he switched to the fast-follower strategy. This was a very astute move, because IBM traditionally introduces its new products first in the U.S. and later in Europe, with a two-year average time lag. Olivetti has three research laboratories in the U.S. that are also used to gain intelligence on forthcoming IBM moves. As soon as Olivetti finds out what IBM is doing, it starts a crash program to develop a similar product for the European market, to be ready in two years, and thus catch up with IBM in Olivetti's home market.

As a consequence of this major change in strategy, the Olivetti central laboratory in Ivrea, Italy, which was performing advanced research in many areas, was dissolved. Many of the key people left, others were reassigned to operating units where their job was to adapt and implement technologies developed by the U.S. Olivetti laboratories or acquired from other American companies.

To summarize, the choice of a technological strategy has a profound impact on personnel and organization, and a change of strategy will require careful advance planning and adequate time for implementation. Therefore, corporate management needs to be directly involved in these decisions.

Chapter 7

The Role of Technology in Developing Corporate Strategy

In the previous chapter, we reviewed technological strategies that are applicable to a company's (or business unit's) homogenous product line. We will now discuss the role of technology in developing the overall strategy of a corporation (or of a multiproduct business unit in the case of a diversified company).

Review of the strategic planning process

The basic purpose of strategic planning is to develop the preferred strategy that will lead to the attainment of the business goals of the corporation (growth in revenue, profitability, market share, productivity, customer and employee satisfaction, image, and so forth). The classic strategic planning process follows a simple six-step logic:

1. Description of the mission and business scope of the corporation, its objectives, and goals.
2. Analysis of the external environment (market and technology trends, dynamics of competition, and so forth) and of resulting opportunities and threats.
3. Analysis of the resources available to the corporation (human, financial, technological assets, customer goodwill) and determination of its strengths and limitations.
4. Formulation and evaluation of possible strategies that will lead to the fulfillment of corporate objectives and selection of the preferred strategy.
5. Determination of what resources are needed to implement the strategy and how the missing resources will be obtained.
6. If all the required resources cannot be obtained, or if the risk is too high, corporate objectives are revised and the entire process is repeated.

Within this overall process, technology may take three different roles of increasing significance for planning the firm's strategy. Technology may (1) be an element of the reactive planning mode, (2) lead proactively the planning process, or (3) become the driver of corporate strategy.

Technology in the reactive planning mode

In the reactive planning mode, technology is utilized, as any other corporate resource, to capitalize on opportunities and counter threats. Going back to the example of GE Medical Systems, market and competitive analysis uncovered a major threat to GE leadership in X-Ray medical equipment—the new EMI CAT scanner. Reacting to this threat, GE decided to adopt the fast-follower-and-overtaker strategy and mobilized the required resources, primarily technology. Some technology was available within the GE Medical Systems Business Unit, but most had to be obtained outside the unit, from the GE corporate R&D Center, outside consultants, suppliers, and customers (leading medical research clinics and physicians).

A few years later, technological gatekeepers at GE were able to track the emergence of a new medical diagnostic imaging technology—magnetic resonance imaging (MRI). They correctly forecasted that this new technology, because of the improved diagnostic capabilities and the absence of X-Ray radiation, would lead to the development of a new multi-billion market. In this case, GE Medical Systems chose to follow the first-to-market strategy and mobilized the required resources, primarily new technologies, such as nuclear resonance physics and superconducting magnets. As a result of these successful reactions to the EMI threat and to the emergence of a new technology (not originated within the company), GE now remains the world leader in the medical diagnostic imaging systems business.

Technology in the proactive planning mode

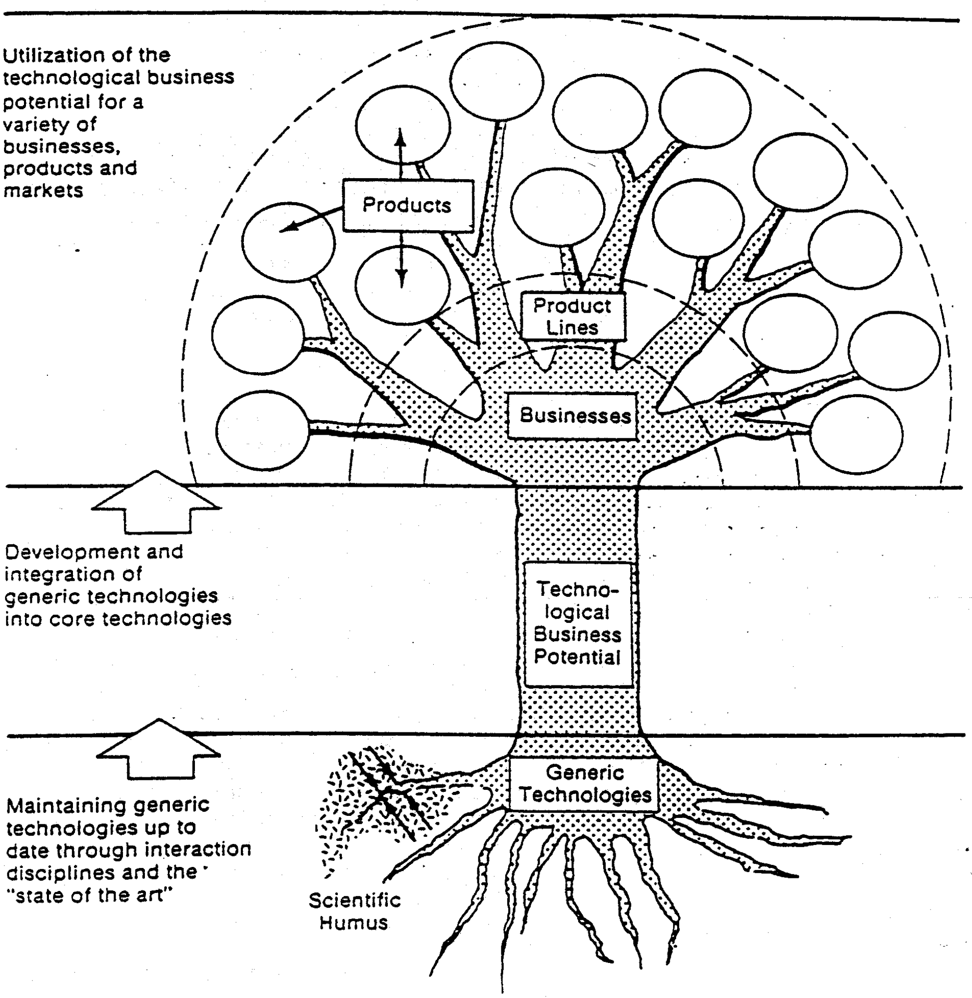
In contrast to the reactive planning mode, technology is used proactively to establish the strategy for the corporation on the basis of a unique competitive advantage. Obviously, there must also be an existing and potential market that the corporation couples to the technology, creatively and entrepreneurially. The case of a new technological venture, Map Info, started by four RPI graduates, well illustrates this strategy. As part of a project in computer science, these students developed new proprietary software for displaying maps of any type and scale on personal computers and relating graphically a data base (for instance, street addresses) to the map. Previously, this process could only be done on a minicomputer, such as a VAX, or mainframes with a software package costing generally $50,000 or more. The same students also took the author's entrepreneurship course and learned how to develop a new technological venture and a business plan.

They adopted the first-to-market strategy with the rapid market penetration substrategy and set the price of their software package at an amazingly low $750, which made it accessible to the majority of the 15 million-plus owners of PCs worldwide. Since it was founded on December 19, 1985, the company has raised about $1 million in venture capital, hired 31 new employees, and has reached an annual sales level of $3 million, with customers in 26 countries. It has also achieved profitability, although most of the earnings are being reinvested in expanding the product line. In this case, Map Info did not react to the environment and follow the wave. Rather, after studying the market and selecting the most favorable segment, they proactively "made the wave"!

Technology as the driver of corporate strategy: the Japanese "bonzai tree"

There is a third mode, in which technology or, better, the technical knowhow of the company determines and drives corporate strategy. This mode originated in Japan, has been studied in France, but is

Figure 8 The "Bonzai Tree" Showing the Driving Role of Technology in a Japanese Company



not well known in the U.S. Therefore, we need to go back to the Japanese concept of the "bonzai" tree, that is, a miniature tree (*zai*) carefully grown in a wooden tray (*bon*). In the ancient Japanese culture, trees were considered to be the dwelling place of the Shinto gods, and their image is often utilized to represent a human society and even the organization and spirit of a company. Recently, this concept has been used to depict the driving role of technology in Japanese corporations (Figure 8).

The *roots* of the tree symbolize the interaction of the company with the world of science and technology. These roots extract from the scientific humus the generic technologies needed by the corporation and transfer them as a vital lymph that allows the tree to produce fruits, that is, profitable products, which will be harvested (for a fee!) by the customers. The advanced research and technological gatekeeping functions reside in the roots.

The *trunk* of the tree symbolizes the technological and business potential of the company. It represents the knowhow and specific capabilities of the company that are later embodied into its product lines: core technologies, market and business knowhow, managerial competency. While new roots and branches may grow and old roots and branches wither, the tree trunk has a very long life. Its role is to develop and integrate the generic technologies into the core technologies that represent the company's unique technical strengths. The applied research and especially the development function reside in the trunk.

The *branches* symbolize the utilization of the technological and business potential of the company in various business sectors and product lines. Their role is to obtain input from the environment (light from the sun) and produce fruits that can be harvested. The design, application engineering, and production and marketing functions reside in the branches.

With this concept, the corporation may be defined as a combination of different activities connected together by a common integrated technical knowledge. The strategic implication of this concept is momentous: The company will target a very broad spectrum of products, markets, and industries where its unique technological knowhow may be converted into competitive advantage. The annual report of the Japanese company Toray, world leader in the production of carbon fibers, presents the company's products and markets according to the bonzai tree. Toray is truly diversified into varied business sectors (mechanical, automotive, marine, aerospace, transportation, energy, and even the sport industries) and in products (from tennis rackets to fuel cells, to linear motors, to brake discs), but technology determines the strategy and keeps the company together. The strategic planning process is used for the selection of the most promising new market/product combinations and for their implementation, always maximizing the utilization of the company's unique technical knowhow.

Recalling the strategic challenges presented at the beginning of this study (Chapter I) and the present business trends towards innovation, entrepreneurship, and intrapreneurship, it appears that some American corporations will gradually evolve from the technologically reactive to the proactive strategic planning mode, and perhaps to technology as the ultimate "driver" of their strategy.

Chapter 8

Conclusion

TECHNOLOGY, particularly fast-moving high-technology, entails major strategic opportunities and also major risks for the corporation. The risk of adopting advanced technologies still in the start-up stage may be high, but the risks of sticking to mature technologies and being overtaken by aggressive competitors may be higher.

Therefore, corporate officers and managers must take responsibility for linking technology to the business strategy of the corporation (or of its strategic business units). They should set up a *system* (formal or informal, depending upon the company's culture and capabilities) for assessing, planning, developing, and implementing the core technologies that will impact upon the future of their company. They should also *manage:*

— The *acquisition of technology,* internally through R&D and externally through cooperative R&D, licenses, joint ventures, and so forth.

— The *utilization of the company's technological assets,* preferably by *incorporating the company's unique knowhow* into new or improved innovative products, processes, or systems, or by *selling or exchanging* these assets for tangible benefits, such as royalties and equity participation in joint ventures.

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