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The Emergence of Technology Strategy

A New Dimension of Strategic Management

John Friar and Mel Horwitch

ABSTRACT. This article deals with the rise and character of modern technology strategy. The current elevation of technology to a strategic variable is discussed, and the key forces behind this trend are identified. The current blending of two previously distinctive private-sector modes of innovation—small high-technology firm entrepreneurialism and large corporate industrial R&D—is highlighted. A conceptual framework, consisting of decisions and trade-offs along the three dimensions of competitive strategy, domain and structure, is given. Empirical support, based on both industry-level and firm-level data and analysis, is presented. It is argued that, over the past few years, the approaches used by corporations for developing and acquiring technology have become more numerous and varied with the relative significance increasing for internal decentralized entrepreneurial units and external approaches. A stabilization or consolidation of technology strategy approaches, however, may take place in the near future. Still, the emergence of modern technology strategy has permanently changed the landscape of the strategic management field.

The real acceptance of technology's strategic importance is a relatively recent phenomenon. In the past, viewing technology as an essential part of corporate strategy was largely absent in strategic management thinking and practice.[1] The emergence of *technology strategy* today, however, is a significant, enduring and novel aspect of modern strategic management.

This article discusses the background, dimensions and implications of this elevation of technology to a strategic variable. A historical and conceptual overview is provided. Then the significant directions of technology strategy patterns are docu-

John Friar is finishing his Ph.D. dissertation on the relationship between technological advance and competitive advantage in the medical diagnostic equipment industry. He is a member of the Management of Technology and Strategy group at the Sloan School of Management, MIT. Mr. Friar received an MBA from the Harvard Business School, and has worked as director of marketing and planning for a division of North American Philips Corporation. His previous experience also includes engineering work on the Space Shuttle as an employee of Draper Laboratories.

Mel Horwitch is a member of the corporate planning, policy and strategy group at the Alfred P. Sloan School of Management, MIT. He has worked in both government and private industry, and has written extensively on strategic management, technology, energy affairs, and large-scale programs and projects. His most recent book is Clipped Wings: The American SST Conflict. *He is completing a book on modern strategic management.*

mented and analyzed at two levels: industry and firm. First, the relevant changing patterns in four very different kinds of technology-intensive industries are examined: personal computers, diagnostic ultrasound equipment, manufacturing technology, and biotechnology. Second, the technology strategy patterns in a number of large technology-intensive firms are analyzed. Finally, the implications of the ideas and findings in this article and an assessment of future directions for technology strategy are discussed.

Before discussing specifically the characteristics of modern technology strategy, the activity itself requires some further elaboration and explanation. Technology strategy can meaningfully be distinguished from other overlapping technology-related aspects of business behavior. Technological innovation traditionally has been portrayed largely as a subject separate from other management practices, including strategy. Technology has been studied in considerable depth as part of R&D management and the process of technological innovation; it has been reviewed as a determinant of organization structure; and it has been seen as being a critical factor in influencing the evolution of the international product life cycle.[2] Modern technological innovation, furthermore, is now recognized as a complex activity. One important aspect of our growing understanding is the realization that technological innovation is a process, made up of diverse parts, varied participants, complicated patterns of evolution and information feedback loops, and potentially lengthy time durations. Great emphasis is now placed on the roles of "market pull" and "user needs." Important research continues to highlight the key role of people, as champions, entrepreneurs, or technology-familiar managers, in effectively promoting and accelerating innovation.[3] Moreover, while such activities as R&D management, new product development, process improvement, or even overall technological innovation obviously form part of technology strategy, they do not usually encompass such key aspects of corporate strategy as top management involvement, high-level planning, and strategic resource allocation.

Both technology and strategy, moreover, are ambiguous concepts. "Technology" can be viewed as the ability to create a reproduceable way for generating improved products, processes and services. This capacity is both a formal and informal activity. Its result can be radical or incremental in nature. "Strategy" is probably an even more ambiguous term than technology. Definitions of strategy abound. As seen in Figure 1, however, there is general agreement that strategy involves the interplay and trade-offs of three sets of dimensions: present and future, internal and external considerations, and explicit (*e.g.*, formal) and implicit (*e.g.*, informal) managerial practices.

For much of the postwar period in the United States, technology and corporate strategy were distinctly separate fields and areas of activity. The key ingredients for technological vitality in industry appeared to be the vigorous functioning of different kinds of technological innovation and the active interplay of two distinctly separate forms of private-sector technological innovative activity—small-company and large-scale-corporation innovation.[4]

Corporate strategy as described above was usually not part of a small firm's management repertoire. Instead, strategy—if it related to technology anywhere—belonged to the realm of the large-scale corporation and, hence, its R&D activities. But even in this case, technology was not usually considered in truly strategic terms.

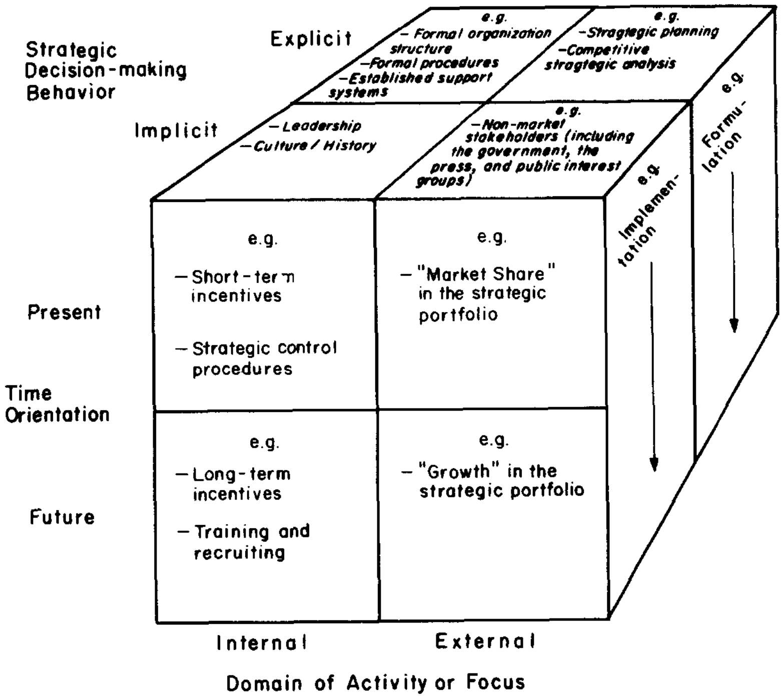


FIGURE 1. The dimensions of corporate strategy.

Technology strategy has a top-level and total-form perspective. It is, in essence, that set of activities by which management chooses its technological activity, allocates the resources for its technological undertakings, and structures the overall context for the development and maintenance of the technological resources that support the long-term strategic direction of a firm. Technology strategy has intimate ties with the other functional strategies of a corporation, including marketing, manufacturing, finance, and human resources. Moreover, it has a profound impact on the business strategies of a firm, such as in creating synergies between businesses, in extending or transforming the life cycles of various products, or in creating opportunities for forward and backward vertical integration.

Five Historical Forces

The recognition of technology as a top-level and strategic concern for a corporation was due to the convergence of at least five historical forces that, by the 1980s, had pushed technology to the fore.

The first element was a growing reaction to the seeming dominance of strategic planning that occurred during the preceding decade of the 1970s. This earlier period was a kind of "Golden Age" of strategic planning that was supported by strategic planning staffs within firms and a network of information and analysis industries and institutions that included strategic consulting firms, business schools, and strategic-level, computer-based models. To a greater or lesser degree, much of the center of gravity in strategic management shifted from an earlier tradition in strategic management that had emphasized such imprecise and informal general management factors as leadership, interpersonal skills, experience, and vision to the seemingly more rigorous, objective and formal standards associated with strategic planning. Intense international competition increased, however, with foreign competitors succeeding apparently without the help of strategic planning staffs or consultants. Moreover, previous assumptions associated with strategic planning, such as the universal benefits of large market share, were questioned. Consequently, strategic planning came under attack. It was increasingly seen as possibly a costly piece of overhead. As corporations began to reconsider the process of creating real wealth or value, they turned toward technology as a key vehicle for accomplishing this goal.[5]

A second source of the intensifying interest in technology as a strategic weapon was the obvious success of small high-technology firms in a host of emerging technology-intensive industries, such as instruments, semiconductors, computers and software. Here was another model for creating new wealth, neither dependent upon strategic planning staffs and consultants nor upon huge industrial R&D facilities and units. Instead, the key ingredients for success appeared to be risk-taking, technological champions and entrepreneurs, intense commitment, informal and fluid organization structures, and fast response to changing market conditions. Some large corporations, like Hewlett-Packard and 3M, successfully incorporated many of these attributes into their own management systems and cultures. By the 1980s, other large firms were attempting—not necessarily successfully—the same thing at the expense of strategic planning and industrial R&D.[6] Again, this attention to new ways of organizing for innovation tended to raise the level and priority of technological decisions and deliberations in the corporation, often to the strategic level.

A third source that tended to promote technology as a strategic variable was the obviously high priority given to technology by the foreign competitors of US firms, particularly the Japanese. The growing importance of developing new technology in the corporate strategy of Japanese firms was increasingly recognized in the US. MITI openly admitted that its future lay in higher value-added industries and technological innovation.[7] As one Japanese scholar observed, by the late 1970s, with the successful completion of MITI's dramatic and significant VSLI Project in semiconductors, Japan moved from imitation to innovation.[8] Eventually, by the early 1980s, the sheer impact of the acknowledged Japanese successes in such technology-intensive global industries as robotics, semiconductors, computers, telecommunications and ceramics would alone raise the role of technology in US firms to a high level of significance.[9]

A fourth element that increased the visibility of technology was the concurrent rise in status and importance of manufacturing as a strategic weapon. During the 1960–1980 period, the competitive role of manufacturing had diminished in the US. Two main trends were responsible for this decline in the strategic use of manufacturing by American management. First, the manufacturing function increasingly became a subsidiary activity in the corporation. It grew more and more technical, and was often equated with the more discipline-based concerns of operations research. Moreover, the main purpose of manufacturing—or operations management, as this field was increasingly termed—was, more often than not, to fine-tune the task of mass production. The strategic role of manufacturing until the decade of the 1980s was largely ignored.

But, again triggered especially by effective foreign competition, the key strategic significance of such manufacturing considerations as flexibility, quality, rapid change-overs, and process trade-offs was increasingly recognized. Moreover, the concurrent incorporation of new electronic and information technologies into manufacturing (which resulted in new capabilities for manufacturing operations, and altered the meaning of traditional experience-curve and operations management concepts) also accelerated the rediscovery of manufacturing as a strategic weapon. By the early 1980s, the lonely cries of a decade earlier for a broader and more elevated view of manufacturing were finally echoed with increasing frequency, intensity and support.

Significantly, those calling for an enhanced place for manufacturing issued similar pleas for technology. In fact, it is somewhat surprising and ironical that the calls for giving technology a strategic role initially emanated more from the strategic wing of the manufacturing area than from the management of technology field itself.[10]

The final element that gave impetus to the rise of technology as a strategic variable was the force of ongoing research and thinking in the fields of strategic management and the management of technology. In the former area, in spite of the apparent victory of the formal and technocratic methodology represented by strategic planning, the older general management tradition had by no means vanished. By the end of the 1970s, as the vulnerability of strategic planning became increasingly apparent, the value of the lessons from the older general management approach was once again acknowledged, and new research rediscovered this perspective. Works emphasizing leadership, implementation, corporate culture, and a return to fundamentals were once more widely embraced.[11] Practically all such strategic thinking stressed the importance of innovation. Simultaneously, within the management of technology field, a base of knowledge and concepts was developed. Technology was increasingly seen as important and often critical to the whole firm. A dissatisfaction with the traditional fragmentation and the narrow specialties of this field took place. There were calls for a broad firm-level synthesis of the management of technology area, which tended to become strategic in perspective.[12]

By the early 1980s, the full impact of these five historical forces—the negative reaction to strategic planning, the success of the small high-technology firm, the increasingly strategic importance allocated to technology by foreign competition (particularly the Japanese), the related rise in status of manufacturing as a strategic weapon, and the supportive relevant thinking and research in the fields of strategic management and the management of technology—was visible, widespread, and powerful. Technology strategy has become an important management activity in the corporation.

Major Characteristics

What are the major characteristics of this phenomenon, termed technology strategy, that emerged in the early 1980s? In order to discuss this issue, both a historical and a conceptual view are required.

A historical perspective is important for recognizing just how fundamental the current transformation, represented by the rise of technology strategy, is. In fact, there has been a strategic blending of two earlier paradigms for private-sector technological innovation: small high-technology firm entrepreneurship and large-scale corporate innovation. Through approximately the 1970s (as seen in Figure 2), private-sector US technological innovation could logically be viewed as comprising two paradigms or ideal types: 1) Mode I—small high-technology firm entrepreneurship; and 2) Mode II—large-scale corporation R&D.[13] Mode I might well be designated the "Silicon Valley Model" of innovation. It represented a fundamentally new and

Key Mode Attributes	← Inputs		→	← Internal Processes		→	Output
Important Modes of Tech. Innovation	Technology/ Skills Available	Environment	Market	Goal Setting	Communication System	Organization Structure	Innovation: Product Line or Process or Systems
MODE I*	-emphasis on exploiting existing & known technologies -technological capabilities restricted to few areas -key technological skills reside in top management	-contained & definable	-markets for the product are few & definable	-goals are set by top man -goal-setting is informal with few actors involved -options open to the firm are few	-informal -few people -dissemination of information does not demand complex system due to few recipients	-organization -structure emphasizes few sub-units & informality -top management gets involved in all activities in the organization	-typically a product or a product-line scope tends to be limited by the technological capabilities of the top management
MODE II**	-complex in defined product or process areas -skills consist of technological as well as non-technological, line marketing, in these areas. Mode II is concerned with existing & non-existing technologies which they help to develop	-multiple & complex but still definable	-markets for innovations are multi-user markets & complex	-innovation goals are partially set by formal systems -firm has several technological options to choose from -top management may or may not be directly involved in identifying or pursuing technological options	-complex due to several organizational levels, formal & informal -affecting communication is possible but difficult to achieve	-organization tends to be complex, divided into product groups, divisions, etc. -often different sub-units have conflicting attitude & priorities -corporate boundaries are definable	-large number and/or complex products & processes

Source: Mel Horwitch, "The Blending of Two Paradigms for Private-Sector Technology Strategy" in Jerry Dermer, ed., Competitiveness Through Technology: What Business Needs from Government (Lexington, MA: Lexington Books, Inc., forthcoming).

*Technological innovation process in small, entrepreneurial, high-technology firms.
**Technological innovation in large, multi-product, multi-market and/or multi-divisional corporations.

FIGURE 2. A comparison of the characteristics of the two modes of private-sector technological innovation.

dramatic phenomenon in American business history, where highly trained and well-educated technological entrepreneurs, during the period from the 1950s through the 1970s, created small high-technology firms in regions known for high-quality universities, such as Silicon Valley in California, Route 128 in the Boston area, the Research Triangle in North Carolina, and Route 1 near Princeton, New Jersey.[14]

The salient features of Mode I included: a strong commitment generally to a single, narrow or focused technology area; a comparatively small, informal and changing organizational structure; a technological champion as head of the firm or part of the top-management team; and an overall climate and style of entrepreneurship and risk-taking. The key frequent weaknesses of Mode I organizations were also apparent: an absence of basic business skills, the huge and sometimes negative role that the personality traits of the founder could play, a lack of various kinds of resources, and the dependence usually on a single technology or product-market area.

Co-existing with Mode I firms and even pre-dating them were Mode II corporations and the traditional technological innovation process within them. Technological innovation in the Mode II multi-division, multi-product and multi-market context often presented a generally different set of behavior patterns and challenges than those found in a typical Mode I environment. The major managerial problems for Mode II technological innovation through the 1970s, as seen in Figure 3, usually included making strategic choices or trade-offs along at least three sets of dimensions: types of technological innovation, the specific technologies to develop, and the timing or positioning of technology introduction into the marketplace (in Figure 3, Freeman's classification terminology for this last dimension is employed—offensive, defensive, imitative, dependent, traditional and opportunist—but other classification schemes may be equally appropriate).[15]

Even after strategic decisions are more or less established, the Mode II corporation still had to deal with a number of complex internal strategic activities, including technological resource allocation, monitoring and evaluation of technological undertakings, the design of an appropriate structure, the location of the innovating activity, internal technology transfer, and the relationship between the early R&D work, the developmental work, and the operating divisions. The linkages between technological innovation activity and ongoing and pervasive formal procedures represented a particularly important difference between Mode II and Mode I environments. Similarly, the significant and often novel opportunities for technological synergies were also a major aspect of Mode II technological innovation.

A glaring weakness that was often attributed to traditional Mode II conditions was the absence of crucial entrepreneurial and risk-taking behavior patterns that were associated with Mode I. Cultivating and maintaining such behavior in the large corporation has become a major challenge for modern technology strategy. Although this earlier postwar paradigm of private-sector technological innovation involved the separate functioning, co-existence and interplay of two distinctive modes of technological innovation, effective and vigorous Mode I-like behavior was increasingly viewed as important for most successful innovations, even in a Mode II context.

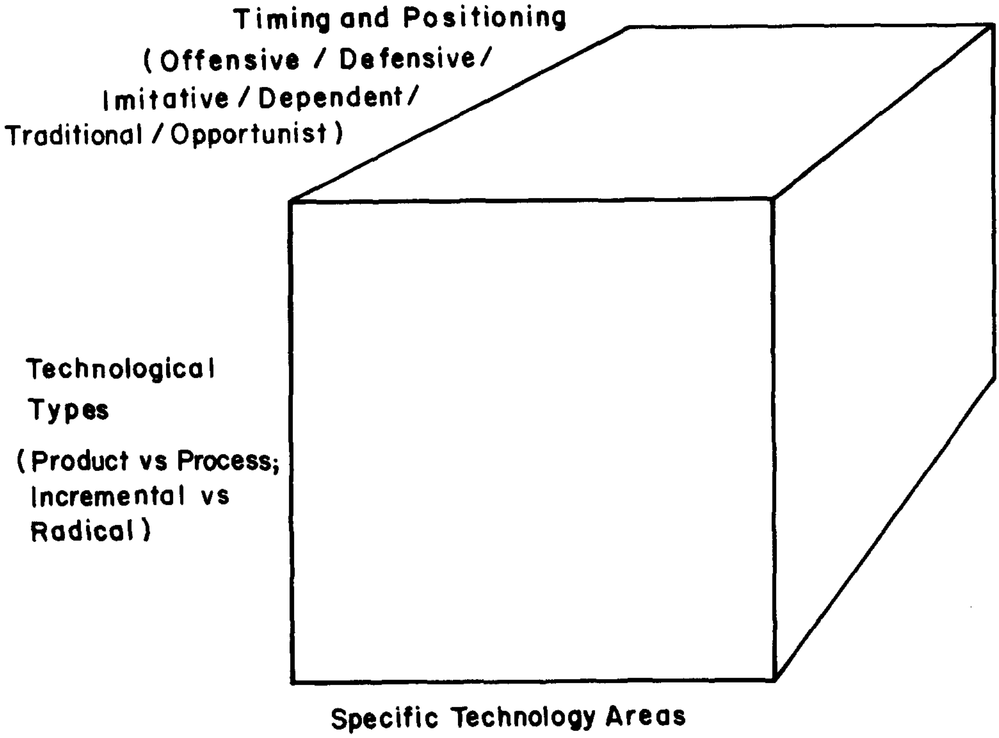


FIGURE 3. Mode II concepts for technological strategic choices through the 1970s.

Source: Mel Horwitch, "The Blending of Two Paradigms for Private-Sector Technology Strategy" in Jerry Dermer, ed., Competitiveness Through Technology: What Business Needs from Government (Lexington, MA: Lexington Books, Inc., forthcoming).

Fading Boundaries

By the early 1980s, as technology became increasingly strategic, the boundary between the two major forms of private-sector technological innovative activity—small-firm and large-corporation innovation—began to fade. This blending of these previously distinctive modes is a salient feature of modern technology strategy.[16] Small technology-intensive firms are becoming increasingly "professional" in managerial practices. They are savvy about the capital markets, and can negotiate effectively with large firms. Meanwhile, large corporations are increasingly attempting to install within their organizations and cultures Mode I structures and behavior. The previous separation no longer holds. Out of this fundamental blending, modern technology strategy has emerged. Now a complex array of trade-offs, relationships and linkages has to be managed. In order to better understand this new situation, a conceptual framework is helpful, and is presented in Figure 4.

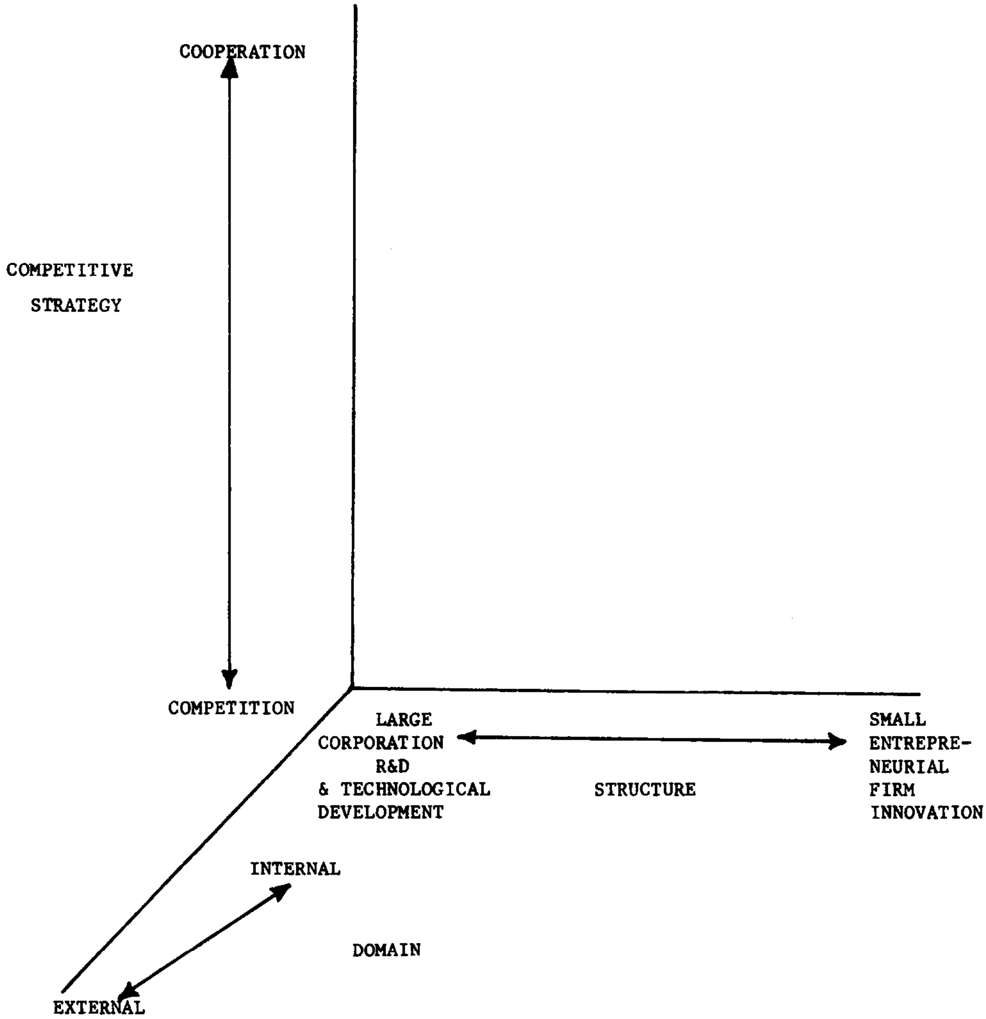


FIGURE 4. Elements of modern technology strategy.

Large modern technology-intensive corporations are making technology strategy decisions along three dimensions: competition vs. cooperation (competitive strategy); internal vs. external development (domain); and traditional R&D organizations, *e.g.*, the industrial R&D facility, vs. decentralized entrepreneurial units (structure).

Achieving the appropriate set of multiple trade-offs along these dimensions is one of the major tasks in technology strategy today, but it does not necessarily lead to making simple choices.

To take but one example related especially to the dimension of structure, recent research, based on the multi-business-unit PIMS database, has uncovered many distinctive kinds of technology-intensive businesses.[17] Seven were identified. Four are in the industrial products area (Established Suppliers, Fast Movers, High-Tech Job Shops, and Stalled Giants), and three are in the consumer products area (Established Diversifiers, Dominant Specialists, and Laggers). Moreover, focusing on the intra-organizational linkages of vertical integration, shared facilities, or shared marketing, a complex group of success patterns was found. Success was found to depend upon the type of technology-intensive business, the criteria for success (in this case, market share or ROI), and structure. Clearly, designing a sound structure for effective technology strategy involves more, for example, than merely possessing or trading off mainstream industrial R&D and decentralized venture units.

The Emergence of Modern Technology Strategy: An Industry-Level Perspective

In order to document more fully the extent and dimensions of modern technology strategy, two types of information will be presented. First, a brief review of representative technology-intensive industries will be given. Second, an analysis of the technology strategies of representative large US technology-intensive corporations will be made.

Personal Computers

The personal computer industry, one of the clearest examples of an entrepreneurially launched technology-intensive industry, illustrates on a macro level the current transition of technology strategy. In the latter half of the 1970s, the true spark for this industry came from an entrepreneurial small-firm environment that was made up of hobbyists, publicists and promoters, technological champions, and entrepreneurs.[18] As seen in Table 1, all three of the major initial start-up firms in the personal computer industry, MITS, IMSAI and Processor Technology, failed in the marketplace, and did not create sustainable businesses. Although they were very

TABLE 1. Market share (by dollar sales) of the US personal computer industry

Company	1976	1978	1980	1982
MITS	25%			
IMSAI	17%			
Processor Technology	8%			
Radio Shack		50%	21%	10%
Commodore International		12%	20%	12%
Apple		10%	27%	26%
IBM				17%
NEC			5%	11%
Hewlett-Packard			9%	7%
Other	50%	28%	18%	17%
Total	100%	100%	100%	100%
Total Units	15,000	200,000	500,000	1,500,000

Sources: Gary N. Farner, *A Competitive Analysis of the Personal Computer Industry*, MIT, Alfred P. Sloan School of Management, unpublished Master's Thesis, May 20, 1982, p. 18. Deborah F. Schreiber, *The Strategic Evolution of the Personal Computer Industry*, MIT, Alfred P. Sloan School of Management, unpublished Master's Thesis, May, 1983, p. 7.

different kinds of firms, these early personal computer firms in different ways often lacked certain essential business skills. Their fates also frequently hinged on some counter-productive personality traits of the founding entrepreneurs.

But there was an important "second wave" in the early personal computer industry, beginning with the appearance in 1977–1978 of one totally new firm, Apple, and two large, established firms that entered from other industries, Radio Shack-Tandy and Commodore International. All three firms entered the personal computer industry at about the same time. For different reasons, all three were successful.

Apple reflected the best of small-firm behavior: an innovative and adaptable technology and product design, skilled technological champions at the top, a strong entrepreneurial drive, and a remarkably effective, informal and spirited organization. Radio Shack-Tandy had a good product design, excellent service and support, and a superb marketing and distribution system. Commodore International had good marketing and low-cost production through vertical integration.

During this "second wave," small and large computer firms remained more or less distinct. But there was a vital interplay between them as people flowed from one firm to another, and with this flow, the transfer of technology and relevant managerial knowledge and technique took place. There was co-existence, but separateness.

But the traditional small firm/large firm dichotomy appears to have broken down in personal computers. As indicated in Table 1, a dramatic development in the industry occurred with the entrance of IBM. The firm quickly captured a huge market share, particularly in the business market. In June 1984, a sample survey of 37 *Fortune* 500 companies found that 95% had as primary personal computer hardware IBM, PC, PC/XT, or PC-compatible machines.[19]

Much of IBM's market success in personal computers lies in the novel way IBM structured itself to enter the personal computer industry. The firm went outside its mainstream R&D processes to establish an Independent Business Unit (IBU) to develop personal computers. The IBU worked separately from the rest of IBM, and created, for IBM, a non-traditional product and product strategy. The IBM PC uses off-the-shelf components and an outside operating system, MS-DOS. Also, its operating system architecture is open, so that third parties can develop software. Moreover, instead of solely selling through its own sales force, IBM also sells PCs through retail outlets.[20]

On another front, in August 1983, IBM boosted its equity position in Intel, its key PC microprocessor supplier, to about 13.7%. Rather than just making a good financial investment, IBM appeared to be taking strategic action to protect its and America's technological base by strengthening a key US innovator.[21] IBM had both created a small-firm-like organization within its overall large-corporation structure, and had established a number of novel external linkages.

More generally, as indicated in Figure 5, the personal computer industry has witnessed an increasing number of key strategic linkages that spans types of technological innovation, countries, and organizations. AT&T has bought 25% of Olivetti, and Olivetti quickly designed and produced an IBM-compatible machine for AT&T to sell, beginning in July 1984. AT&T also has contracted with Convergent Technologies, a small firm in the Silicon Valley, to develop and produce a Unix-based PC.[22] Meanwhile, the Japanese ceramics firm, Kyocera, has built highly successful lap computers for Radio Shack-Tandy, NEC and Olivetti.[23]

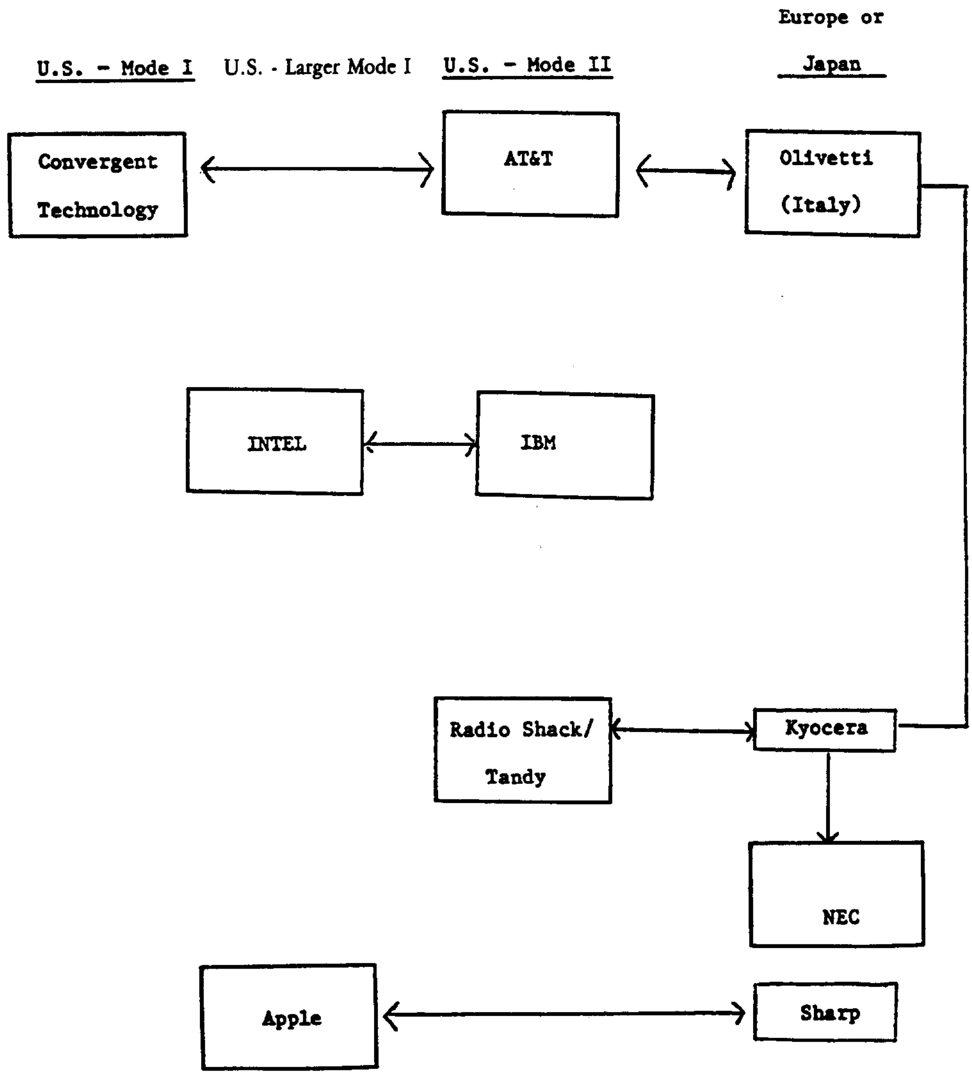


FIGURE 5. A selected list of linkages in the personal computer industry, 1983–1984.

Sources: Various Issues of InfoWorld in 1983 and 1984.

Finally, Apple now has Sharp making its flat LCD display for its trim IIc computer. Apple also markets Canon's new laser printer in the United States, while Canon markets Apple's MacIntosh computer in Japan. Both firms are working on software for the MacIntosh for the Japanese market.[24]

Diagnostic Ultrasound Equipment

The medical electronic equipment industry can be divided into five broad segments: diagnostic, monitoring, therapeutic, prosthetic, and surgical support.[25] The medical electronic equipment market in the US was estimated at $3.7 billion in 1983 with the diagnostic segment, which comprises about 350 US firms, accounting for 45% of that total. Worldwide sales of the entire industry are estimated to be twice that of US sales, so the worldwide market was about $7.4 billion in 1983. The worldwide market is estimated to be growing at 15–20% annually, although some of the subsegments are growing at twice that rate.

In many ways, this industry is the prototypical high-technology industry. Because the markets are large and growing rapidly, many firms have entered the industry. Entry barriers are low. Manufacturing consists of component assembly, with components typically comprising 85% of the cost of the equipment. So manufacturing value-added is very low. Distribution and service can be provided by manufacturers' representatives until a firm reaches a scale to perform direct sales. Capital has been available from venture capitalists, although high levels are not needed, because the research costs are often bootlegged from large firms, universities, and government research groups. Many new firms are divisions of companies not originally in the medical electronic equipment industry. They have used expertise from other fields to enter these markets.

The product value-added that a company can provide is in its proprietary assemblage of common components. This ability, however, is readily duplicated and hard to defend.

No single company markets products in all major categories of equipment, although some companies emphasize breadth of product line. No company, moreover, dominates any single product line, because no company has been able to transfer product-line dominance across countries.

The industry, then, appears to be highly fragmented with the number of firms still growing. The industry is not one that is likely to go through the well-known cycle of birth, growth, maturation and decay. Continued product technology advancements, both major and incremental, are expected. A dramatic shake-out of the industry, then, is highly unlikely.

But the strategic significance of inter-firm linkages in this seemingly hyper-fluid industry is high. Let us take, for example, a segment of this industry, diagnostic ultrasound. About 80 companies now compete in diagnostic ultrasound. The top five companies held less than 50% of the market in 1980. More new companies are expected to enter, and the drive to constantly improve the technology is likely to continue.

Still, perhaps because of this constant churning, strategic linkages are crucial, as seen in Figure 6. Advances in the state of the art are considered to have come mostly from small, start-up companies, but even these companies have acquired technology from external sources. ATL started with technology it licensed from the University of Washington; Hoffrell, from the University of Pittsburgh; Unirad, from Battelle; and Diasonics, from Searle and Hitachi. Small companies, moreover, have acquired other companies for their technologies, such as Diasonics' acquisition of Varian and Fischer's acquisition of EMI Ultrasound.

Large companies have also used diverse avenues to enter and to develop various ultrasound technology segments. An example is General Electric. GE entered the ultrasound market by first hiring people away from Litton, and then selling a product originally developed by Litton and modified by Xonics. The rest of GE's prod-

GEC, Ltd.

- Acquired Picker
- Acquired Cambridge Instruments
- Licensee of SRI and Hitachi.

General Electric

- Bought technology from Electra-Physics (Litton) and hired Litton people.
- B-scan product modified by Xonics
- Linear array developed by Yokogawa
- Phased array developed by Analogic Corporation
- Mechanical sector developed by Second Foundation

Johnson & Johnson

- Acquired Technicare (Ohio Nuclear, Unirad, Scientific Advances, Battelle)
- Acquired Irex (Joint venture with Hoffrell)

Philips

- Acquired Rohe Ultrasound (sold Kretz equipment)
- Licensee of Matsushita
- Supplied by Hoffrell

Siemens

- Sold Diasonics equipment in Europe
- Acquired Searle's line
- Licensee of Matsushita

SmithKline

- Started as joint venture with General Precision Corporation
- Acquired rights to mechanical sector from Indianapolis Center for Advanced Research
- Licensee of Mediscan (licensed Xerox)
- Formed SKI and sold 80% to Xonics

Squibb

- Acquired ATL (Licensee of Univ. of Washington and SRI)
- Acquired ADR (Start-up from Unirad)

Diasonics

- Start-up from Searle
- Acquired Varian
- Licensee of Hitachi
- Joint development with Hitachi

Toshiba

- Supplied to Litton
- Hired Litton people

Hoffrell

- Licensee of University of Pittsburgh
- Licensor to Philips and Cambridge Instruments (Picker)
- Joint venture with Irex (Johnson & Johnson)

Fischer

- Acquired EMI

Unirad

- Acquired by Ohio Nuclear and Technicare (Johnson & Johnson)

Xonics

- Owns 80% of SKI (SmithKline)
- Developed product for GE

Litton

- Spawned G.E. and provided B-scan
- Spawned Toshiba; original licensee of Toshiba

Searle

- Spawned Diasonics
- Acquired by Siemens

FIGURE 6. Technology linkages in the US diagnostic ultrasound industry, 1977–1982.

uct line was developed by Analogic Corporation, Yokogowa, and Second Foundation. GE has competed in ultrasound, then, by using outside technology to enter the product markets and by using internal development to create some further advances.

Other large corporations have used acquisitions to enter: Squibb acquired ATL and ADR; Philips acquired Rohe; Johnson & Johnson acquired Technicare. Along with GE, several firms are licensees of Japanese technology: Philips, Diasonics, Picker and Siemens. Joint ventures for the development of technology have also been evident; two examples are SmithKline with General Precision Corporation and Diasonics with Hitachi. Finally, large firms have taken equity positions in smaller firms, *e.g.*, SmithKline's 20% control of SKI, to maintain linkages with firms performing ultrasound technology development.

The diagnostic ultrasound industry, therefore, is characterized by a rich and varied technology-strategy environment. In 1985, about 80 companies competed in this segment. Many small start-up firms were vying for market share against large corporations. But both the small firms and the large corporations are using a broad range of techniques to develop and to acquire technology, including strategic linkages. Even in an apparently fluid technology-intensive setting, a blending of previously distinctive modes is taking place.

The Manufacturing Technology Industry

The same pattern of an evolving set of complex technology strategies is now manifested in the manufacturing technology industry, an industry with little of the postwar small-firm entrepreneurial experience that was part of the personal computer or diagnostic ultrasound equipment industries.

The US machine tool industry played an important and venerable role in US technological development and business history. During the latter half of the 19th century, the machine tool industry served as the vital link for developing and transferring technology to American industry as a whole.[26] But by the mid-20th century, the US machine tool sector was clearly in a mature phase, and had lost much of the technological vitality and importance as a salient industry that had characterized it in an earlier era.

In the postwar period until about 1980, this industry was not very glamorous or exciting from the point of view of technology strategy.[27] Defined as "power-driven machines, not hand held, that are used to cut, form or shape metal," the machine tool industry itself is a relatively small sector of the US economy, comprising about 0.12% of the GNP and 0.10% of the US employment in 1982. Most US machine tool firms have traditionally been small, closely held companies with narrow product lines. The industry is not highly concentrated with the four largest firms in 1977 accounting for 22% of industry shipments. Both sales and, to a lesser extent, employment are highly cyclical. Research and development expenses, capital investment outlays, and growth and productivity are all relatively low.

In 1982, in constant dollars, R&D expenses declined to about the same level that they were in 1975. The global market share of the US machine tool industry decreased from 25% in 1968 to 20% or less in the 1970s. In terms of both growth and productivity, the US machine tool industry during the 1973–1981 period fell way behind US manufacturing as a whole, and, in the case of productivity, behind durable goods manufacturing. During the postwar period, until perhaps very recently, the US machine tool industry generally exhibited a short-term outlook, concerned mostly with annual financial goals.

The US machine tool sector, therefore, seemed to resemble the prototypical "smokestack" or "sunset" industry. Under the impact of effective global competition and the apparent failure to exploit or keep up with various new technologies in manufacturing, such as new materials, software, CAD/CAM and automation, the US machine tool firms have become progressively less profitable, and have lost significant market share. Moreover, there was generally an absence of significant small-firm innovation activity with the possible exception of the robotics field.[28] Even in robotics, however, much of the technological leadership during the 1970s shifted to Japanese companies. In addition, the relatively large US firms also did not generally exhibit significant technological R&D activity or leadership. In machine tools during the 1970s, there was very little of the creative and vital interplay between distinctly small-firm and large-firm innovation that was manifested, for example, in the "second wave" of the early personal computer industry. Instead, the US machine tool industry stagnated, and various global competitors took quick advantage of this situation.

But such a gloomy picture of machine tools actually needs revision today. If the definition of machine tools is broadened to encompass manufacturing process technology as a whole, rather than just metal-bending or metal-cutting, then the industry is now clearly experiencing a major restructuring. The development of software, CAD/CAM, robots, systems and, ultimately, full-scale factory automation is dramatically changing what had seemed to be a stagnant, sunset industry into a technologically vigorous one that possesses some of the new patterns of technology strategy manifested in more stereotypical modern technology-intensive industries. As seen in Figure 7, the industry is becoming more complex in terms of proliferating "strategic groups,"[29] and is attracting a wide array of new entrants, ranging from new, small, high-technology firms to established large manufacturing firms like General Electric, Westinghouse and IBM.[30]

The current pattern of technology strategy in the manufacturing process technology industry, therefore, also exhibits an increasing blurring of the various distinctive types of technological innovation and a growing profusion of linkages between types of innovation and between firms.

These trends can be seen by focusing on one strategic group within the whole manufacturing process technology industry, robotics.[31] The overall American effort to develop robotics until about 1980 was fragmented, limited to a few players, and lacked the support of crucial stakeholders, such as large industrial concerns and the government. As seen in Figure 8, until very recently, practically all robotics activity in the US was concentrated in a few companies with two firms, Unimation and Cincinnati Milacron, together accounting for greater than 50% of the US market share through 1982. Like machine tools, robotics in the US was in the industrial R&D backwater, and, except for Cincinnati Milacron and a few small firms, was largely a low-priority R&D item until the 1980s. The involvement of large manu-

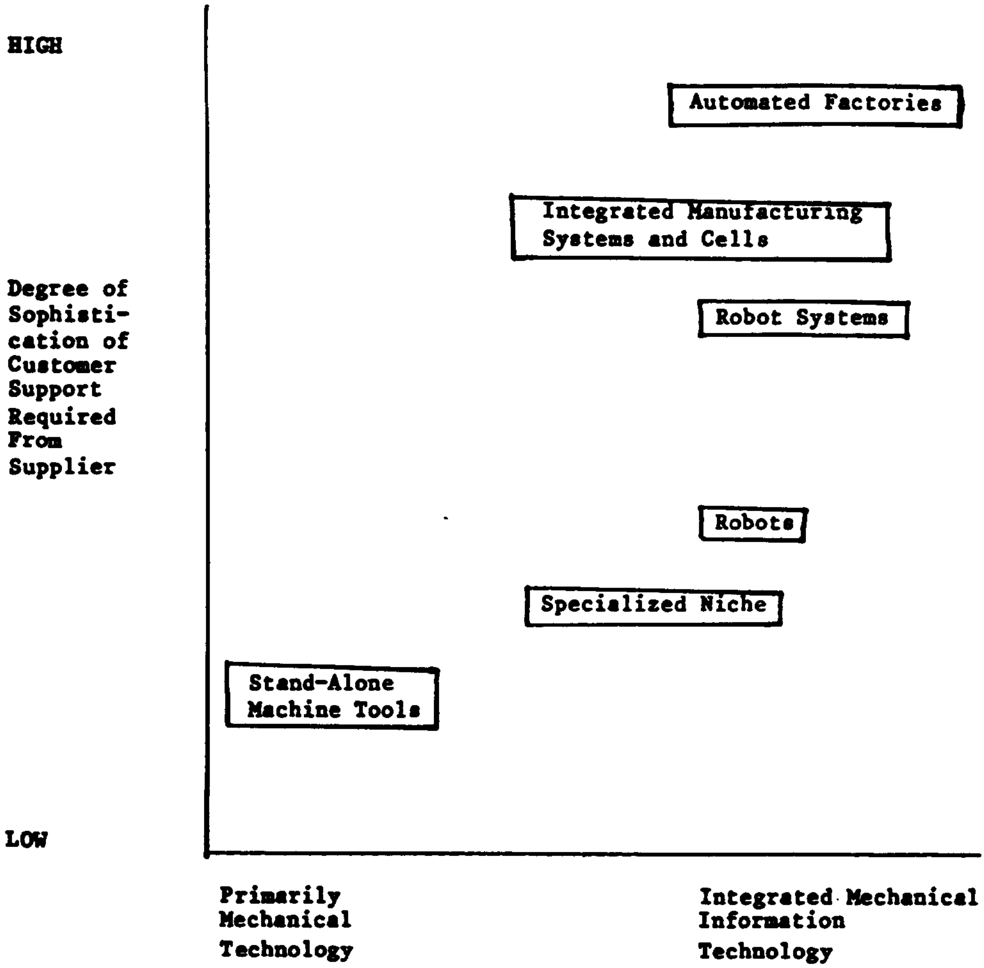


FIGURE 7. Strategic groups in the manufacturing technology industry.
Source: National Research Council, *The U.S. Machine Tool Industry and the Defense Industrial Base* (Washington, D.C.: National Academy Press, 1983).

facturing enterprises and corporations with strong capabilities in the key technologies and frequently with huge captive markets was practically non-existent until the 1980s.

By 1980, however, the situation was beginning to change. The growth rate of US robotics sales was accelerating, and—just as significant—important new entrants had appeared. The new entrants, as seen in Table 2, were not primarily new start-up ventures. Instead, they represented large established enterprises with strong manufacturing and technological skills.

Large and small firms are now fully represented. A technology-based industry

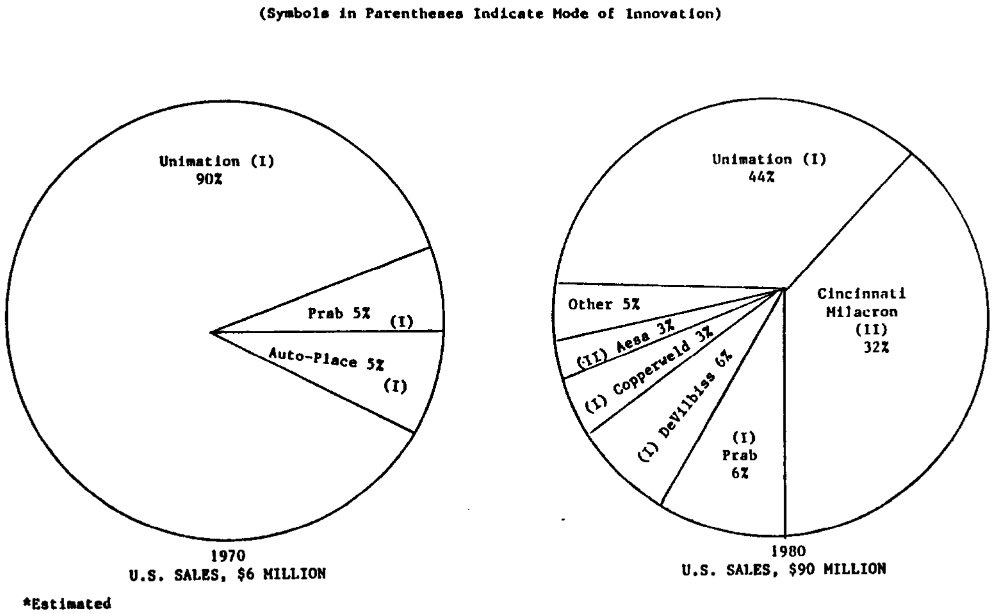


FIGURE 8. US robotics industry sales and market share.
Source: L. Conigliaro, *Robotics Newsletter*, Number 9, Bache Halsey Stuart Shield, Inc., 1982; and modified by authors.

is now on the verge of a probable take-off. Figure 9 shows that, at some point in the early 1980s, the rate of growth of the US robotics industry began to increase significantly.

In addition, as seen in Figure 10, suddenly a whole, rich array of linkages, many of which are international in character, is being established through licensing agreements, joint ventures, and mergers and acquisitions. A new complex set of technology-strategy patterns now exists in the US robotics industry, perhaps just in time.

The Biotechnology Industry

The biotechnology industry is still another type of technology-based industry.[32] It is young and global. Almost from the start, it has possessed a full set of complex strategic relationships. All forms of modern technology strategy are represented in this sector, as seen in Figure 11.

The major US small firms, such as Genentech, Biogen and Cetus, have equity and/or research linkages with several large corporations throughout the world. A number of major large corporations, such as Eli Lilly, Monsanto and—to a more limited degree—DuPont, in addition to sizeable internal R&D activity, are actively linked in diverse ways with other firms. In fact, these intertwining relationships are global in nature, as seen in Figure 12, which illustrates US-Japanese strategic connections.

TABLE 2. Market Share: U.S. based robot vendors (1980–1983)

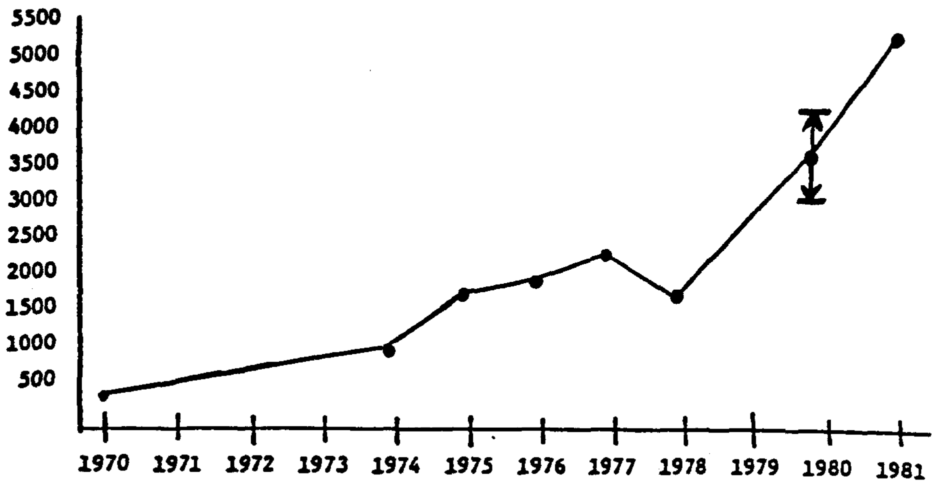
	1980	1981	1982	1983
Unimation	44.4%	43.8%	32.1%	22.8%
Cincinnati Milacron	32.2%	32.2%	21.0%	16.2%
DeVilbiss	5.5%	4.2%	7.4%	6.7%
Asea Inc.	2.8%	5.8%	8.7%	7.2%
Prab Robots Inc.	6.1%	5.3%	4.2%	4.2%
Cybotech	—	—	1.4%	2.3%
Copperweld Robotics	3.3%	2.3%	2.3%	1.8%
Automatix	0.4%	1.9%	4.2%	7.6%
Advanced Robotics Corp.	1.9%	0.5%	3.5%	3.2%
Mordson	0.8%	1.6%	2.5%	2.5%
Thermwood	—	0.6%	1.6%	1.4%
Bendix	—	—	1.4%	2.3%
GCA Industrial Systems	—	—	1.0%	2.9%
IBM	—	—	0.7%	3.0%
GE	—	—	0.9%	1.1%
Westinghouse	—	—	0.4%	1.5%
U.S. Robots	—	—	0.6%	1.5%
Graco	—	—	0.6%	1.5%
Mobot	0.9%	0.4%	0.8%	0.8%
GM/Fanuc	—	—	1.5%	3.0%
American Robot	—	—	—	0.6%
Textron	—	—	—	0.3%
Nova Robotics	—	—	—	0.3%
Control Automation	—	—	0.1%	0.3%
Machine Intelligence	—	—	—	1.1%
Intelledex	—	—	—	0.6%
Other	1.7%	1.3%	1.5%	1.7%
	100.0%	100.0%	100.0%	100.0%

SOURCE: L. Conigliaro, *Robotics Newsletter*, Number 9, Bache Halsey Stuart Shield, Inc., 1982.

The Emergence of Modern Technology Strategy: A Firm-Level Perspective

The companies selected for our firm-level analysis of modern technology strategy were from those US-based *Fortune* 500 companies that had spent at least $80 million on R&D in 1982, as listed by *Business Week* (March 21, 1984). It was assumed that companies which had spent this much money on R&D had large R&D organizations extant with the capabilities to initiate a complex set of research projects. Furthermore, these firms would also be able to locate and acquire technical skills that were not presently in-house.

Given the apparently huge capability of such firms, the selection criteria for the companies to be studied was purposely biased toward firms that *a priori*, if possible, would want to keep as much of their technology development under direct control.



Point	# of Robots	Date	Source
A	200	1970 (April)	Engelberger, First National Symposium on Industrial Robots, 1970
B	1200	1974 (Dec.)	Frost and Sullivan, U.S. Industrial Robot Market, 1974
C	2000	1975 (Dec.)	Frost and Sullivan, The Industrial Robot Market in Europe, 1975
D	2000	1976 (Dec.)	Eikonix Technology Assessment, 1979
E	2400	1977 (Dec.)	Eikonix Technology Assessment, 1979
F	1600	1978 (Dec.)	American Machinist 12th Inventory, 1978
G	3000	1980 (Jan.)	Walt Weisel, Prab Conveyors
H	3500	1980 (June)	Business Week, Verfied by Cincinnati Milacron
I	3200	1980 (Dec.)	General Motors Technical Staff, (Bache, Shields estimate)
J	4000	1980 (Dec.)	Walt Weisel, Prab Conveyors
K	5500	1981 (Dec.)	Seiko Inc., Marketing Dept.

FIGURE 9. Estimates of US robot population, 1970–1981.

SOURCE: David Schatz, The Strategic Evolution of the Robotics Industry Unpublished Master's Thesis, Sloan School, MIT, May 1983.

LICENSING AGREEMENTS

Licensee	Licensor
Kawasaki Heavy Ind. (Japan)	Unimation
RN Eurobotics (Belgium)	Arab
Can-Eng. Mfg. (Canada)	"
Murata Machinery (Japan)	"
Binks (U.K.)	Thermwood
Cyclomatic Ind.	"
Didde Graphics Co.	"
DeVilbiss	Trallfa (Norway)
Nordson	Taskawa (Japan)
Admiral Equip. Co.	"
Bendix	
Automatix	Hitachi (Japan)
General Electric	"
Interred	"
Graco	Nolaug (Norway)
United Technologies	Nimak (W. Germany)
RCA	Dainichi Kiko (Japan)
I.B.M.	Sankyo Seiki (Japan)
General Electric	DEA (Italy)
" "	Volkswagen (W. Germany)
Westinghouse	Olivetti (Italy)
"	Hisubishi Electric (Japan)
"	Komatsu (Japan)
	Jobs Robots (Italy)
Lloyd Tool and Mfg.	

JOINT VENTURES

J.V.	Parents
Unimation	Condac, Pullman Corp.
GMF Robotics, Inc.	General Motors, Fanuc
Cybotech	Renault, Randsburg Industries
Int'l. Machine Intell.	Machine Intelligence, Yaskawa
Int'l. Machine Intell.	
Graco Robotics	Graco Inc., Edon Finishing

MERGERS AND ACQUISITIONS

Subsidiary	Parent
Unimation	Westinghouse
PAR Systems	GCA
U.S. Robots	Square D. Corp.
Copperweld Robotics (formerly Auto-Place)	Copperweld Corp.

FIGURE 10. Interfirm linkages in the US robotics industry, 1983.
Source: David Schatz, *The Strategic Evolution of the Robotics Industry*, Unpublished Master's Thesis, Sloan School, MIT, May 1983.

Important modes of Technological Innovation / Home Countries of firms	United States	Japan	France	Other
Small Firm	Genentech Cetus Collaborative Res. Genex Bethesda Res. Labs Agrigchetics Hybritech Molecular Genetics Calgene, Amgen, Collagen Eugenics, Intern'l Plant Res. Inst., Genetics Institute	There are several small biotechnology firms in Japan, including Hayashibara Biochemical Wakunaga Pharmaceutical		Biogen (Swiss & U.S.) Novo Industrie (Den.) Fortia (Sweden)
Large Corporation	Du Pont, Campbell Soup Monsanto, Johnson & Johnson Eli Lilly Fluor Corning Glass Amoco Socal, Chevron Exxon Nat. Distillers Corp. Upjohn, Pfizer, Searle, Merck Mobil Oil, Allied, Koppers, Dennison, Bristol Myers, Dow Chemical, Phillips Phillips Petrol. Occidental Petroleum (Zoecon) DeKalb Agresearch ARCO, GE Union Carbide	Sumitomo Chemical Diiachi Seiyaku Mitsubishi Chemicals & Petrochemicals Kyowa Hakko Kogyo Toatsu Mitsui Chemicals Asahi Chemical Ajinomoto Takeda Chemical Daicel Chemical Kirin Brewery Mochida Pharmaceutical Nippon Kayaku Nippon Oil Oji Paper Sanyo Chemical Suntory Shionogi Green Cross	Rhone-Poulenc Moet-Hennessy Elf Aquitaine BSN-Gervais-Danone Air Liquide Roussel-Uclaf Lafarge Coppee	Grand Metropolitan (U.K.) Shell (U.K. & Neth.) B.P. (U.K.) INCO (Can.) Hoffman - La Roche (Swiss) Kabi Vitrum (Sweden) Sandoz (Swiss) Ciba-Geigy (Swiss) Imperial Chemicals (U.K.) BASF (W. Ger.) Hoechst (W. Ger.)
Multi-Organization	Whitehead Inst. (MIT)	Bio-Technology Project (MITI)	Transgene Societe Lyonnaise [Institut Pasteur]	Celltech (U.K.) NEB (U.K.)

FIGURE 11. Representative and partial list of institutions participating in the biotechnology industry.

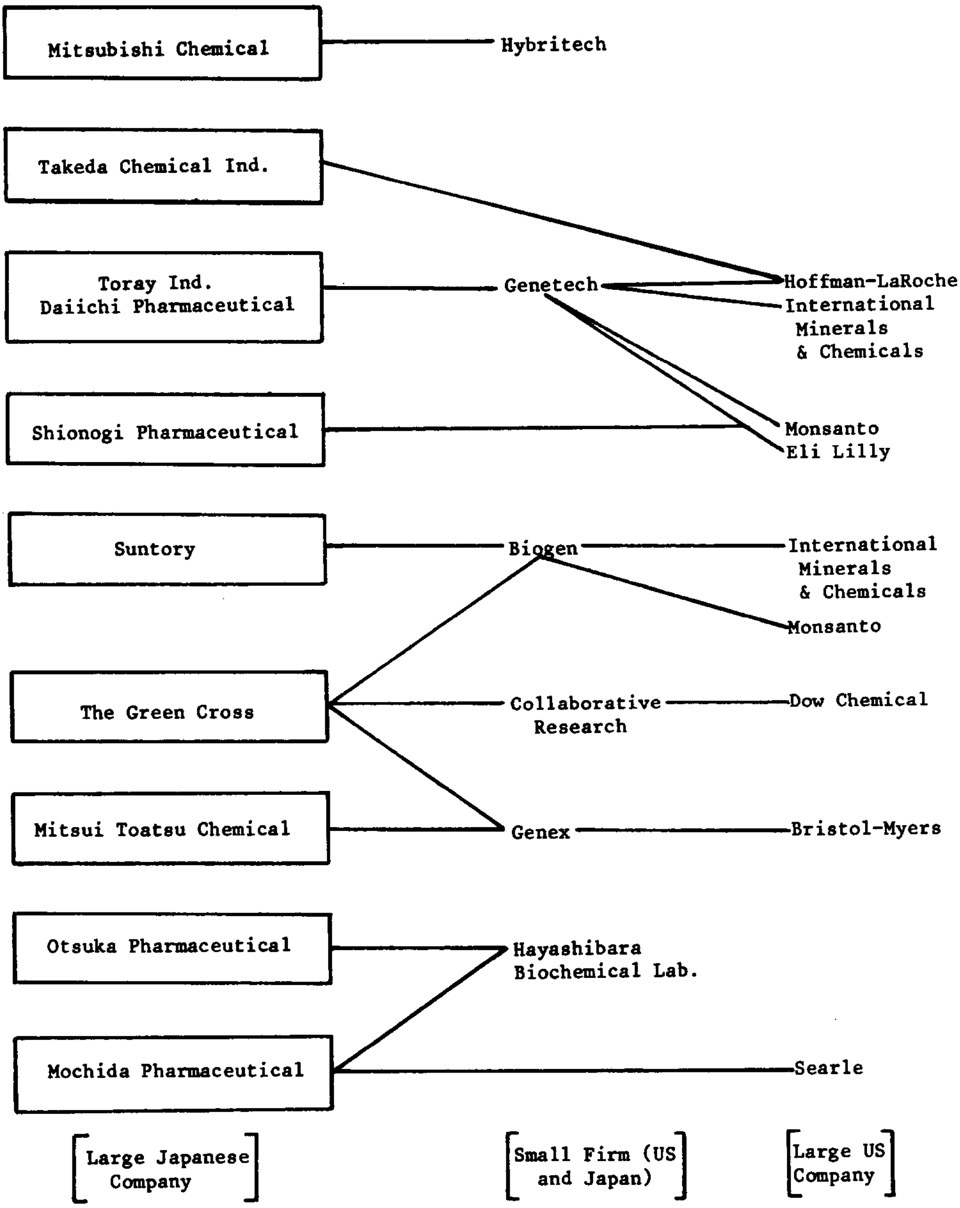


FIGURE 12. Relationships between US and Japanese biochemical companies.

We wanted to test, then, even against this bias, whether such companies were using and are going to continue to use a greater variety of technology strategy approaches and a greater proportion of external techniques for technology development than they had employed in the past.

Several methods for technology development and acquisition were identified (Table 3).[33] Technologies developed in the industrial R&D laboratory or in entrepreneurial subsidiaries represent the fruits of internal techniques of development.

TABLE 3. Technology development and acquisition approaches

Internal

1. Technologies Developed Originally in the Central R&D Lab or Division
2. Technologies Developed Using Internal Venturing, Entrepreneurial Subsidiaries, Independent Business Units, etc.

External

3. Technologies Developed Through External Contracted Research
4. External Acquisitions of Firms for Primarily Technology-Acquisition Purposes
5. As A Licensee for Another Firm's Technology
6. Joint Ventures to Develop Technology
7. Equity Participation in Another Firm to Acquire or Monitor Technology
8. Other Approaches for Technology Development or Acquisition

Source: Adapted from Edward B. Roberts, "New Ventures for Corporate Growth," *Harvard Business Review*, July–August, 1980.

The remaining techniques are considered to be the external methods of technology development or acquisition.

Ninety-seven companies met our R&D expenditure criterion, and are listed in Table 4.

Sixteen companies were selected to give a preliminary indication of the direction of our study results. The 97 companies fell within 24 industry groupings (*Business Week*'s classifications), while the subset of 16 fell within seven industry groupings (Table 5).

Data were gathered by three methods: 1) comparative analysis of *Wall Street Journal Index* citations; 2) analysis of annual reports and 10-Ks; and 3) phone interviews based on a common questionnaire.

The *Wall Street Journal Index* citations for the first 16 firms studied for the years 1978 and 1983 were scanned for any mention of a company's use of one of the techniques of technology acquisition or development. The years were chosen by taking the most recent year and the year five years previous to it.

The results of the *Index* search are listed in Table 6. There has obviously been both an increase in the general variety of use of approaches and a significant increase in the use of each individual method of external technology acquisition. Companies that have strong in-house research capabilities have been using, at the same time, more of and a greater variety of external sources.

To test whether the two years chosen for the study may not have just been anomalies, annual reports and phone interviews were used to corroborate or refute the direction of the findings. The annual reports were scanned for any mention of a company's use of one of the techniques. This information was used as a recall aid for the respondents. In-depth phone interviews were completed for ten of the 16 companies. In the phone interviews, respondents were asked questions about methods of technology-strategy planning and about trends over the past five to seven years and for the next five to seven years in the use of technology development techniques. The interviews required two or three respondents from each company and

TABLE 4. Companies that spent more than $80 million on R&D in 1982

Abbott	J&J
Allied	Lilly
Allis-Chalmers	Litton
Aluminum Company of America	Lockheed
Amdahl	Martin Marietta
American Cyanamid	McDonnell-Douglas
American Home Products	Merck
American Motors	Mobil
AMP	Monsanto
Atlantic Richfield	Motorola
ATT	National Semiconductor
Baxter Travenol	NCR
Boeing	Northrop
Bristol-Meyers	Pfizer
Burroughs	P&G
Caterpillar	Phillips Petroleum
Celanese	Polaroid
Chrysler	PPG
Control Data	Raytheon
Corning Glass	RCA
Data General	Revlon
Dart & Kraft	Rockwell
DEC	Rohm & Haas
Deere	Schering-Plough
Dow	Schlumberger
DuPont	Searle
Eastman Kodak	Shell
Eaton	Signal
Emerson	SmithKline
Exxon	Socal
FMC	Sperry
Ford Motor	Squibb
GE	Standard Oil (Ind.)
General Dynamics	Syntex
General Foods	Tektronix
General Motors	Texaco
Goodyear	Textron
Gould	3M
GTE	TI
Gulf	TRW
Halliburton	Union Carbide
Harris	United Technologies
Hewlett-Packard	Upjohn
Honeywell	U.S. Steel
IBM	Wang
Ingersoll-Rand	Warner-Lamber
Intel	Westinghouse
International Harvester	Xerox
ITT	

Source: *Business Week*, March 21, 1984

TABLE 5. Listing of industry groups represented by companies that spent more than $80 million on R&D in 1982

Aerospace
Automotive: cars, trucks
Automotive: parts, equipment
*Chemicals
Conglomerates
*Drugs
Electrical
Electronics
Food & Beverage
Fuel
*Information Processing: Computers
Information Processing: Office Equipment
Instruments
*Leisure Time Industries
Machinery: farm & construction
Machinery: machine tools, industrial, mining
Metals & Mining
*Miscellaneous Manufacturing
Oil Service & Supply
*Personal & Home Care Products
Semiconductors
Steel
*Telecommunications
Tire & Rubber

*Industries from which companies were studied in further detail.
Source: *Business Week*, March 21, 1984

TABLE 6. Technology development activity of selected 16 firms, 1978 and 1983

(# of Publicly Reported Major Instances of Technology Strategy Activities)

Approach	1978	1983
1. R&D Lab	—	1
2. Internal Venturing	0	4
3. Contracted Research	1	7
4. Acquisition of Firms	10	18
5. Licensee	5	9
6. Joint Venture	1	16
7. Equity Participation	0	8
8. Other (Market Another's Product)	5	14
Totals	21	77

Source: *Wall Street Journal Index*, 1978 & 1983.

took about an hour each to complete. (The questionnaire upon which the phone interviews were based is included as an appendix to this article.)

Respondents were asked to allocate the significance of the use of each technology development or technology acquisition activity within the corporation by using proportional measures. One hundred percent represented the entire set of such activities. The change in the proportion over the time period was used as the direction indicator in Table 7.

A negative sign, as in the use of the central R&D lab, for example, does not mean that the activity decreased on an absolute scale. For example, R&D funding was not necessarily cut. Rather, the *relative* importance of the central R&D lab decreased compared to the other technology development or acquisition activities.

The interview results corroborate the *Wall Street Journal Index* search in that the external sources of technology development grew in relative importance over the past few years at the expense of the central R&D lab. There was also a shift in relative importance internally from the central R&D lab to internal ventures or to entrepreneurial subsidiaries for R&D development. For the period that lasted from the late 1970s through the mid-1980s, press reports, annual reports, and the observations of corporate planners and R&D managers generally all indicate an increase in the variety of activities used for technology development and an increase in the relative importance of external sources over internal ones.

In the interviews, we also asked whether these trends were likely to continue in the future. We found different results (Table 8).

The recent and current period of experimentation, which has been characterized by the expansion of both external-oriented approaches and a greater variety generally of types of innovation efforts, may be stabilizing. Many of our respondents paint a near-term future of more consolidation in technology strategy methods. The central R&D lab is not generally predicted to lose any more relative significance, and it may stabilize at its present level of importance. Some of the other activities,

TABLE 7. Directional change in relative significance for the eight approaches for ten companies, 1978–1984

Approach	+	0	–
1. R&D Lab	0	5	5
2. Internal Venturing	4	6	0
3. Contracted Research	2	8	0
4. Acquisition of Firms	6	3	1
5. Licensee	4	5	1
6. Joint Venture	5	5	0
7. Equity Participation	3	6	1
8. Other (Market Another's Product)	3	7	0

\+ increase in relative significance
0 no change in relative significance
– decrease in relative significance

Source: Personal Interviews

TABLE 8. Directional change in relative significance for the eight approaches for ten companies, 1984–1990

Approach	+	0	–
1. R&D Lab	0	8	2
2. Internal Venturing	2	6	2
3. Contracted Research	1	8	1
4. Acquisition of Firms	5	3	2
5. Licensee	5	4	1
6. Joint Venture	5	3	2
7. Equity Participation	2	6	2
8. Other (Market Another's Product)	2	7	1

\+ increase in relative significance
0 no change in relative significance
– decrease in relative significance

Source: Personal Interviews

moreover, may lose relative priority. The broad range of external activities may be used somewhat less, although three activities may continue to grow in relative importance. These activities are the formation of joint ventures, licensing, and the buying of firms for technology acquisition and development.

In the interviews, respondents were also asked about the location in the organizational hierarchy of those people performing technology-strategy planning. Technology-strategy planning was defined as consisting of the following activities:

- Determining what new markets or distribution channels a company can enter with its present technical capabilities;
- Determining the allocation of R&D funding for present major product lines;
- Determining what new technologies to develop or acquire; and
- Determining the methods of technology acquisition or development.

TABLE 9. Location of technology-planning activity

Location \ Company	A	B	C	D	E	F*	G	H	I	J
HQ	X	X	X	X			X	X	X	X
Group	X		X	X						
Division				X	X					
SBU	X	X	X	X			X		X	X
Separate Technical Planning	X									
Lab	X		X	X						
Other										X

*Would not divulge information

Source: Personal Interviews

All the respondents who would discuss their firms' methodologies for technology-strategy planning said that their firms are explicitly performing this planning activity somewhere within the organization (Table 9).

Eight of the ten firms had people at corporate headquarters performing the function, and seven firms had people on two or more levels performing the function. Technology-strategy planning appears to be a multi-level and increasingly general management task.

Conclusion

As can be seen from our discussions and analyses at the historical and conceptual level, the industry level, and the firm level, technology appears to have evolved into a true strategic factor. In practically all types of technology-intensive industries—such as a fluid one like diagnostic ultrasound, one with a typical high-technology evolutionary cycle like personal computers, a revitalized formerly "sick" industry like machine tools, and a strategically managed one like biotechnology—strategic linkages and varied structures for encouraging innovation are increasingly crucial. Also, several corporations appear to have some form of headquarters involvement in technology-strategy planning. Moreover, technology strategy seems to be an increasingly diverse and multi-level activity.

Theoretically, there has always existed a number of approaches for developing or acquiring technology. These approaches can be segmented by development internally or acquisition and development externally. Within each segment, moreover, there exists some choice in the methods of development that are available. For internal development, a firm can use its own industrial R&D staff at the corporate level and within the divisions. A firm can also establish internal ventures or entrepreneurial units to develop technology. Externally, a firm can license technology or contract for its development, form a joint venture, or acquire part or all of another firm for monitoring or buying technology.

Even though these approaches have always existed, it appears that firms have just recently started to experiment seriously with a variety of these approaches. Our data show that firms have substantially increased their relative use of *all* techniques—other than using their own R&D staffs—for technology development. Along with increasing the use of a number of approaches, the firms have been relatively more active in employing the external approaches for development. These trends are corroborated by our analysis of four diverse technology-intensive industries.

There is also a general trend in technology strategy toward more cooperation among competitors for technology development, where firms use such methods as licensing, joint ventures, and acquisitions to share technology. This pattern may indicate that companies are using technology *per se* less and less as a purely competitive tool. As technology becomes more common, competition may shift away from technology and toward other areas, such as marketing and manufacturing.

A factor running counter to such an argument, however, is the prediction that the use of external sources as a group may level off. Intense experimentation of diverse technology strategy methods that stress cooperation may be unstable in the long run because of a lack of direct and full control, and because of the ultimate attraction of being fully and solely competitive for many corporations. If technology is to be used as a competitive weapon, one would predict less growth of cooperation among firms in sharing technology and a decreased growth rate in the use of several external-oriented approaches. According to this argument, therefore, the use of external-oriented methods may peak, and some consolidation may take place with a renewed focus on internal-oriented methods and on external-oriented efforts that are more directly under corporate management's control. The data tend to support this contention.

Technology, in summary, has become a strategic concern to all types of technology-intensive industries. A blending of previous technological innovation modes is taking place. Technology strategy is practiced by most technology-based companies in a multi-level manner. A period of rapid growth in the use of external-oriented strategic practices for technology acquisition has occurred over the past few years. Perhaps the more extensive use of external-oriented methods indicates greater cooperation within the industry, which, in turn, means that technology will be used less as a purely competitive tool. But the use of external-oriented approaches may be reaching an unstable state. Some consolidation back to the internal-oriented practices may be likely. As indicated in Figure 13, there appears to be a limit to intensive strategic diversity as large firms begin to attempt to reassert greater proprietary control over their technological resources.

It is clear that, starting in the middle or late 1970s, we have experienced a tremendous flurry of experimentation, creativity and variety in the area of technology strategy. The earlier and simpler situation, consisting primarily of separate spheres

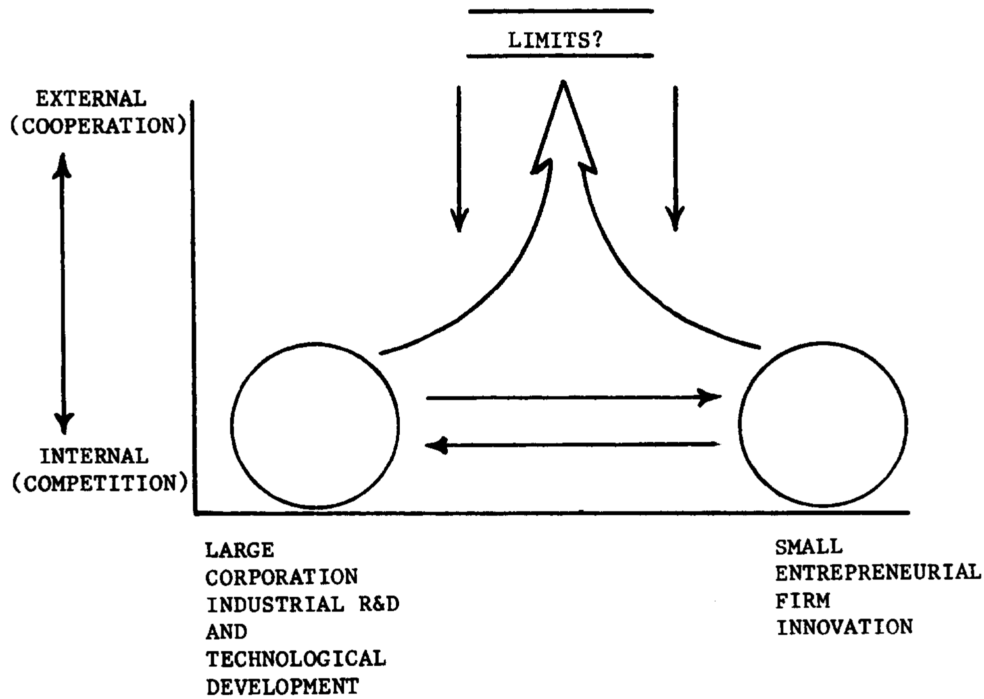


FIGURE 13. Direction of modern technology strategy.

of technological innovation in the private sector, is probably over. But there may also be limits to this exciting wave of managerial development. Complexity may be too great. The desire to internalize or to gain total proprietary control may strengthen. Perhaps, by the 1990s, a mini-backlash may develop. But even then, with some consolidation, technology strategy has emerged. It will remain more varied and complex than technological innovation was two decades ago, and technology will continue to be an essential part of strategic management.

Notes

1. For a discussion of the neglect of technology in the traditional strategic management literature, see Mel Horwitch, "The Blending of Two Paradigms for Private-Sector Technology Strategy" in Jerry Dermer, ed., *Competitiveness Through Technology: What Business Needs from Government* (Lexington, MA: Lexington Books, Inc., in press); and Alan Kantrow, "The Strategy-Technology Connection," *Harvard Business Review*, July–August 1980.
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Appendix
Technology Strategy Survey

This survey is part of a major study on the evolution and current state of technology strategy and technology planning in large corporations that compete in technology-intensive industries. We very much would like your participation. We have also tried very hard to keep this survey brief. Please feel free to make additional comments, elaborate on points, and include supplementary material that you think might relate to your answers or to the subject of the overall study. Of course, all company-specific answers that are not obviously available in the public domain will be kept confidential unless you release them. We will also share our findings with you. Thank you very much for your help.

John Friar
Mel Horwitch
MIT, Alfred P. Sloan School of Management
50 Memorial Drive, E52-556
Cambridge, MA 02139
Tel: 617-253-6672

I. Name ________________________________
Position ________________________________
Company ________________________________
Division,
Subsidiary, etc. ________________________________
Address ________________________________
____
____
Telephone (___)____________________________
Today's Date ________________________________

II-1. Could you please try to estimate how much of your company's overall business (in terms of percentage of sales) is technology-strategy/technology-planning relevant (i.e., in your opinion, uses or could use technology-strategy/technology-planning)?

II-2a-1. In terms of percentage of sales, how much of your current business is now covered by your technology-strategy or technology-planning process?

II-2a-2. Also, if it exists at all, where is explicit and/or formal technology strategy or technology planning practiced in your corporation?

____ Corporate Headquarters
____ The Group (i.e. Multi-Division) Level or Equivalent
____ The Division Level or Equivalent
____ The Business or Strategic Business Unit (SBU) Level or Equivalent
____ At the Central R&D Laboratory or Equivalent
____ At a Totally Separate Technology-Planning Unit or Equivalent (Please explain briefly if possible).
____ Elsewhere (Please explain briefly if possible).

II-2a-3. Also, if it is practical at all, we are interested in at least understanding in a general way *how* technology strategy or technology planning is practiced in your corporation. However, instead of answering an involved set of questions, could you possibly include some of the "raw" forms or other formal documents that are used or that describe your technology-strategy or technology-planning process? Thank you.

II-2a-4. Does your firm have integrative, inter-departmental units that have significant technology-strategy or technology-planning roles. If so, what is this unit(s) called, who heads it (position & name if possible), and when was it formed.

III. We are also very interested in how your methods for technology development and technology acquisitions have evolved and will continue to evolve. We have listed below various methods and approaches for technology development and technology acquisition that are used by modern corporations. Beside each method there are three columns: the late 1970s; the mid-1980s (the present); and the early 1990s. We would like you to give us your best estimate for the entire range of technology-development and technology-acquisition activities practiced at your corporation for each of the three periods. Assuming that 100 percent represents the entire set of such activities, please estimate and allocate the approximate significance of each activity at your corporation using percentages for each period.

	Late 1970s	Mid-1980s (the present)	Early 1990s
1. Technologies Developed Originally in the Central R&D Lab.	____%	____%	____%
2. Technologies Developed Using Internal Venturing, Entrepreneurial Subsidiaries, Independent Business Units, etc.	____%	____%	____%
3. Technologies Developed Through External Contracted Research	____%	____%	____%
4. External Acquisitions of Firms for Primarily Technology-Acquisition Purposes	____%	____%	____%
5. As a Licensee for Another Firm's Technology	____%	____%	____%
6. Joint Ventures to Develop Technology	____%	____%	____%
7. Equity Participation in Another Firm to Acquire or Monitor Technology	____%	____%	____%
8. Other Approaches for Technology Development or Acquisition (Please Explain Briefly)	____%	____%	____%
Total	100%	100%	100%

IV-a. For your most recent fiscal year, could you please list the specific technologies that have been commercially introduced, the specific joint ventures, equity positions or units established, and/or outside firms involved under each of the categories below.

1. Technologies Developed Originally in the Central R&D Lab.

2. Technologies Developed Using Internal Venturing, Entrepreneurial Subsidiaries, Independent Business Units, etc.
3. Technologies Developed Through External Contracted Research
4. External Acquisitions of Firms for Primarily Technology-Acquisition Purposes.
5. As a Licensee for Another Firm's Technology.
6. Joint Ventures to Develop Technology.
7. Equity Participation in Another Firm to Acquire or Monitor Technology.
8. Other Approaches for Technology Development or Acquisition (Please Explain Briefly).

IV-b. Specifically for your current joint ventures, could you please list your partners in the following matrix?

	Small Firms (under $50 million sales)	Large Firms (over $50 million in sales)
U.S. Firms		
Non-U.S. Firms		

IV-c. Specifically for your current equity participation positions, could you please list the firms in which you have equity interests in the following matrix?

	Small Firms (under $50 million sales)	Large Firms (over $50 million in sales)
U.S. Firms		
Non-U.S. Firms		

V. General data on your firm that is related to technology.

a. In what industries do you compete?
b. R&D spending as a percentage of total sales?
c. R&D manpower as a percentage of total manpower?
d. Annual number of patents issued?