Changing Research Cultures in U.S. Industry

Roli Varma
University of New Mexico

Changes brought by the rise of the global economy and the end of the Cold War era have resulted in industry, government, and university rethinking their roles vis-à-vis research and development (R&D), basic versus applied research, and the role of corporate research. Since the mid-1980s, industrial research in the United States has been going through restructuring. Interviews with seventy-two scientists and eighteen managers working in six centralized corporate R&D laboratories in high-technology industry show that a new culture of dependence with a mission-oriented approach is replacing the cherished culture of independence with a result-oriented approach.

As scientists join corporate research and development (R&D), they are shaped by its research cultures. Corporate cultures are generally viewed as a set of social conventions embracing behavioral norms, standards, customs, and the rules of the game underlying social interactions within the firm (Schoenberger 1997). Corporations use cultural norms to manage their scientists and to indicate the working environment and practices. It is through corporate cultures that a company exercises successful control over its research staff. Corporate research cultures are generally produced by top management, especially the laboratory's founders, and maintained by the executives of the corporation (Schein 1992). This is not to deny that a number of subcultures, which are produced by scientists through their activities and relations, coexist.

The corporate research cultures that once existed are changing in many corporate research laboratories in high-technology industries. Numerous changes have been occurring both domestically and worldwide that have caused the R&D landscape to be in considerable flux. The most notable change is an increase in international economic challenges to the

AUTHOR'S NOTE: This research was supported by the National Science Foundation (SBR-9602200). An earlier version of this article was presented at the 4S Annual Meeting in Tucson. I would like to thank Sheila Slaughter, the organizer of the session, for her comments. I am also thankful to David Hess for his comments on methodology.

Science, Technology, & Human Values, Vol. 25 No. 4, Autumn 2000 395-416

preeminence of U.S. competitiveness. For instance, in 1950, the United States accounted for 50 percent of the world's gross national product; in 1960, 40 percent; in 1970, 30 percent; and in 1980, 20 percent (Rock and Rock 1990). Leading corporate research laboratories are rethinking the old research cultures, which supported frontiers of science in an industrial setting (Corcoran 1991; Varma 1995). A business perspective is increasingly challenging the technical one. A recent survey conducted by the Industrial Research Institute (IRI) (1997) shows that R&D directors ranked managing R&D for business growth first, balancing long-term/short-term R&D objectives second, integrating technology planning with business strategy third, and making innovation happen fourth.

This article outlines a number of attributes that show the industrial research cultures have been changing in high-technology industries. These attributes emerged from interviews conducted in 1996 to 1997 with seventy-two scientists and eighteen managers working in centralized corporate R&D laboratories. Based on total R&D funds as a percentage of net sales and the number of R&D scientists per 1,000 employees, I selected two corporate R&D laboratories in the computers–office machinery, electronics-communications, and chemicals-pharmaceuticals industries. Aircraft-missiles, another high-technology industry, was not selected due to extensive federal government involvement. R&D in these industries is concentrated in a relatively small number of companies, and most have experienced some form of restructuring. These industries are more associated with innovation, success in global markets, and spillover effects than other manufacturing industries (Mansfield 1991, 1992). Economic activity in these industries is driving national economic growth around the world. Since most of the changes in research cultures have persisted for almost a decade, high-technology industries are setting trends for other industries.

I selected approximately twelve scientists and three managers from each laboratory who had been in the company for at least five years before reorganization began. I identified scientists by Ph.D. in scientific and engineering disciplines and employment as research scientists in corporate R&D laboratories. Managers were identified by their organizational status irrespective of any similarities with scientists in training and credentials. Since there are layers of managers in any corporate R&D laboratory, I concentrated on only the immediate managers of scientists interviewed. I conducted taped interviews on the recent changes in the laboratory, the criteria being used to generate and evaluate research, the link between research and business, the new partnership between scientists and business managers, communication patterns between research laboratory and business, availability of research funds from business divisions, types of research being carried out, termination of research projects, changes in management philosophy, and the working relationship between scientists and managers.

Old Research Cultures

Centralized corporate research laboratories were established in the beginning of the twentieth century. The central mission of most corporate laboratories was twofold: (1) to employ science and technology to improve existing products and manufacturing processes, and (2) to discover scientific principles and properties of the natural world that could generate new commercial products (Jenkins 1975; Reich 1985; Wise 1985). Many big companies, which were managed division–ally, were diversified and decentralized. These companies had functional laboratories associated with business units whose goal was to improve existing technology. Most companies believed that separating at least one centralized research laboratory from business would provide an internal mechanism for a company's growth and for technological change.

The main objective of these laboratories was scientific discovery. For instance, pioneering research in the central unit of Exxon meant going through the following steps (Eidt and Cohen 1997): select field of interest → probe field → increase scientific understanding → interpret potential technical/ business implications → solicit business support. DuPont's slogan was "Better Things for Better Living through Chemistry." This ideal led to scientists' having autonomy in choosing directions of research. Founders of corporate laboratories believed that scientists needed a free environment to develop ideas. Scientific creativity was viewed as a tender flower that needed protection from outsiders. Popular topics for discussion among corporate managers were the psychology, motivation, and incentives of the scientist. Since an academic environment was seen as compatible with scientific norms, founders of corporate laboratories sought to duplicate it in an industrial setting. An example is Pete Quesada, general manager of the Lockheed Missile Systems Division (LMSD), who decided to run the new research facility "more like a university than a hard-headed business" (Schoenberger 1997, 164). The organizational structure was nonexistent; scientists formed loose coalitions around senior scientists.

Corporate laboratories were built away from manufacturing plants to isolate research from business concerns. An example is Bell Labs, which was organizationally separated from Western Electric in 1925 to permit more effective specialization in research. Another example is LMSD, which was constructed in Van Nuys in 1954, separate from the main headquarters in

Burbank. Similarly, the Xerox Palo Alto Research Center (PARC) was established in Palo Alto in 1970 to shield the new research work from the copier business.

Corporate laboratories were funded from corporate sources to ensure a longer-term and strategic focus. The top management believed that the key to success lay with generous support for industrial research without any immediate financial gains. For instance, Pierre S. DuPont, one of the founders of DuPont, enunciated that

> we should at all times endeavor to have in force some investigations in which the reward of success would be very great, but which may have a correspondingly great cost of development, calling for an extended research of possibly several years, and the employment of a considerable force. (Hounshell and Smith 1988, 45)

Abundant resources and freedom in research were possible because often the heads of the corporate laboratories were scientists by training. They became managers by attending a few days of management orientation to learn to deal with people. Paul Fleury, former director of the Materials and Processing Research Laboratory at AT&T Bell Laboratories in New Jersey, noted that the primary criterion for promotion into management was simply scientific prowess (Corcoran 1991, 136).

By supporting corporate research laboratories, companies have transformed themselves for the better. General Electric laboratory invented central electricity generation, motion picture systems, phonographs, practical telephone transducers, incandescent electric lamps, radio, X rays, the man-made diamond, ductile tungsten, and many new types of engineering plastics. DuPont converted itself from a manufacturer of explosives into a large chemical company by inventing nylon and the complex technology to manufacture synthetic fibers, synthetic rubbers, fluorocarbon, and safety glass. Xerox's PARC Lab invented laser printing and on-screen icons. IBM transformed itself from a typewriter company into the world's most important provider of powerful office technology. Its lab produced the Fortran programming language, relational databases, the D-RAM memory chip, the RISC chip design, token ring, and computer networks. The Bell Labs invented cellular technology, switching networks, the transistor, and the satellite. Many centralized corporate laboratories such as the Bell Labs, IBM, and General Electric produced Nobel laureates.

Decline of Old Research Cultures

Not all research conducted in corporate laboratories was successfully utilized. For example, RCA pioneered innovations in radio and television and established the David Sarnoff Laboratory to ensure RCA's continued technological dominance in its consumer market. However, the Sarnoff Lab did not capitalize on alternative technologies for both disc and tape (Graham 1986). PARC of Xerox succeeded in exploratory research on a computerized office system, but Xerox failed to translate the research results into what later became known as the personal computer (Smith and Alexander 1988). Other companies such as Canon, Hewlett Packard, Apple Computer, IBM, Adobe Systems, and Sun have built sizable businesses based on the research results produced at PARC and market the technology.

Often, companies that invested in research could not successfully utilize the results because the connection between research and innovation was based on a linear model devised by Vannevar Bush (1945): basic research generates new facts and theories that get tested through applied research and then converted into products and processes in the development stage. This unidirectional organization of research had an inevitable problem of persuading each successive function to accept the results of its predecessor in the chain. Each receiving division optimized according to its own situation, leading to delays and redesign at each stage. The complexity added by each stage made the end products rather difficult to manufacture (Sheth and Ram 1989; Souder and Venkatesh 1987).

In the 1980s, U.S. high-technology industries found intense competition from Japan and Europe, which rebuilt their economy, ruined during World War II. U.S. industry was unable to stay ahead technologically and commercially in goods such as transistors, radios, televisions, video cassette recorders, steel, automobiles, fax, and numerically controlled machine tools (Cohen and Zysman 1987; Reich 1988; Dertouzos, Lester, and Solow 1989). Foreign suppliers increasingly met demand for high-technology products in the U.S. domestic market. American inventions and Japanese control of the market showed that those who can make a product cheaper could take it away from the inventor (Thurow 1992). In 1991, after several years of relative decline, Intel of the United States regained its lead over NEC of Japan. By 1995, American high-technology industries regained much of the world market share lost during the previous decade. Yet, there are competitive pressures from several European and Asian economies that seem headed toward prominence as technology developers and a greater presence in global high-technology product markets.

American companies have been responding to competitiveness with financial restructuring. Companies such as Ford Motor and Martin Marietta initiated restructuring in response to competitive share loss and takeover threat, whereas General Electric acted to reduce the gap between actual performance and full potential. RCA and Xerox discarded their mainframe computer units due to IBM domination of large systems. Declining defense budgets led to downsizing of McDonnell-Douglas. Pharmaceutical companies such as Monsanto, DuPont, and Ciba Geigy sought to spread the cost of research on a wider base. Plunging energy prices and global rivals led Exxon to buy Mobil. Unlike earlier, the target for restructuring has been a large corporation, and the rationale has been the greater efficiency (Bowman and Singh 1990). Nearly half of large U.S. corporations went through restructuring in the 1980s at a capital cost of $500 billion. Even though approximately 50 percent were outright failures, companies continue to pursue restructuring in the face of competition (Sifonis 1990). For instance, analysts are skeptical of the recent AT&T and Tele-Communications $31.8 billion merger to provide a two-way cable service capable of carrying digital video and sound and selling advanced set-top boxes that have connectors for video, computer, and telephone (Markoff 1998).

Many corporate laboratories have been dramatically affected because of financial restructuring. For instance, General Electric donated the David Sarnoff Research Laboratory to SRI International, which General Electric acquired in its purchase of RCA. Regional telephone companies formed from the split of AT&T created Bell-core as a separate laboratory, and soon it was sold. Kodak acquired Sterling Drug and then sold. General Motors took over Hughes Aircraft, and DuPont acquired Conoco. General Electric aerospace merged into Martin Marietta, which in turn merged into Lockheed. Kodak transferred research from its central laboratory into operating divisions. Allied Signal, Armstrong World Industries, and W. R. Grace completely eliminated corporate support for central research.

The shifting and shrinking of corporate laboratories is fueled by changes in financial support for research. The growth of U.S. industrial R&D expenditures has slowed in inflation-adjusted dollars since the mid-1980s. From 1979 to 1984, industrial R&D expenditures in 1987 constant dollars grew from $58,271 million to $89,236 million, an average annual increase of 7.4 percent. However, the growth rate of industrial R&D expenditures was reduced to 3.0 percent per year from 1984 to 1989. And, by 1989, constant dollar expenditures actually declined to 1.3 percent. Since then, industrial R&D expenditures have continued to decline in constant dollars, from $94,060 million in 1989 to $93,601 million in 1995 (National Science Foundation [NSF] 1996, 4/5, 107). During the entire 1985 through 1995 period, industrial R&D expenditures have been virtually flat. Most of the cutbacks in industrial R&D funds occurred by companies in manufacturing industries. Since 1991, IBM, AT&T, General Electric, Kodak, Texaco, and Xerox have cut $1.75 billion, $500 million, $500 million, $200 million, $90 million, and $50 million, respectively, from their annual R&D budgets (Cauley 1995, B1). Since the mid-1990s, there has been a tremendous increase in industrial R&D expenditures, but most of the funds are being directed to applied R&D.

In addition, many leading companies have been involved in restructuring their centralized corporate R&D to link research directly to development, engineering, and manufacturing—known as business divisions or components (Varma 1995). There has been a growing perception among corporate executives that corporate laboratories are not helping business to develop relevant technology. For instance, Arno A. Penzias, vice president of research at Bell Laboratories and a Nobel laureate, declared that "the test is not going to be whether we do good science or not. The test is: Is the company going to be healthy or not?" (Corcoran 1991, 136). Louis V. Gerstner, IBM's chairman, announced, "I want this to be something more than brilliant irrelevance. I want something substantive to come out of this" (Lohr 1998, D3). Lewis S. Edelheit (1998, 21), senior vice president of General Electric Corporate R&D said, "Researchers have to be vital parts of the team on every major new program in every business."

New Research Cultures

With restructuring, research in corporate laboratories is being conducted in a market-pull context. Earlier, R&D was intuitive, with little link to business; now, the concept of partnership between research and business has emerged as the main character for corporate R&D. Centralized corporate R&D laboratories are teaming with business divisions, customers, suppliers, universities, and industrial laboratories. Below, I identify a number of attributes, which in their combination suggest the emergence of new research cultures in industry. These attributes show the differences between old and new research cultures in industry rather than differences in new research cultures among various corporate laboratories studied.

1. Decentralization of Funding

Many corporate laboratories have been pursuing decentralization of R&D funding and control. The balance of their funding has shifted from corporate sources to business divisions, which are more closely monitored through customer-contractor relationships. Earlier, funding for corporate R&D laboratories was centralized; it was generated by taxing various business divisions. Research was viewed as a valuable investment for the company's growth, and a premium was placed on stability in funding. Now, most research funds are being generated by contracts from company's business divisions. Leading high-technology companies such as General Electric, Bell Laboratories, Xerox, Kodak, and IBM have changed their funding structure from less than one-third being contracted by business divisions to more than one-half. Funding for R&D is being perceived as a cost.

As one scientist explained,

> The biggest change I have seen here is in the funding structure. When I first started here, we were funded primarily from discretionary funds. . . . We taxed different components of the company. They had to contribute certain amounts of money that went into our research. . . . In the last ten years, we have developed a new funding system in which most of our funds are coming from internal and external contracts. . . . A small sum still comes from discretionary funds, but it is really small.

Another said,

> At the beginning of each year, lab and business managers will sit together to identify key goals for the Center. . . . These goals become the basis of funding from the business components. . . . We decide on programs within the goals identified to get funding approved from components.

One manager defended, "The important thing to remember is that business components cannot cut funding to us. . . . They have to give us money despite the fact they have the freedom to give the contract to [university]." Another said, "True, our lab is going through some financial stress. Our funding from the headquarters has shrunk. . . . We are doing more with less money. . . . But, we are not alone. Most labs are under some financial pressure."

Laboratories in computers–office machinery and electronics-communications have experienced greater cuts in centralized funding for research than laboratories in chemicals-pharmaceuticals. It is mostly because drug-related research tends to be long term, taking more than ten years. Such time frames demand some stability from resources.

2. Business-Driven Research

The decentralization of research funding has brought technical and business interests together at the business-unit level for product and process innovation. Earlier, research was conducted on the basis of generic interests of the company. Research was supported if scientists could show that the technical knowledge generated eventually would be beneficial to the company. Business criteria were in the background. Technical interests dominated the link between research and business. Scientific disciplines, rather than product lines, organized many centralized laboratories.

As one manager explained,

> When we had our funds from the corporate headquarters, our scientists worked on projects that were not really connected with [the company's] businesses. Once components contributed money for research, there was very little connection between what the components put in and what their reflected needs were.

Another said, "The corporate headquarters gave a certain amount of money to the Center and basically said, do the best you can. Make new ideas for the future." Scientists acknowledged that "in the old system, we were doing research for technology's sake. . . . We produced dazzling results. It was not important if that technology was needed by the company or if results had any bearing on the business."

Now research is being carried out in the context of immediate business interests, and this objective is present from the beginning. The goal is to fit business needs into research and not the other way around. R&D managers are actively involved in generating business creativity into research from the start by thinking about cost of research, potential benefits from the investment, manufacturing feasibility, commercial possibilities, competitive analysis, and distribution plan. As one manager said, "We can't pride ourselves merely on scientific ideas we generate. . . . We need to pride ourselves on products that come out of our lab." Another said, "You have to look attractive to the business. The best way you could do this is by demonstrating that you can accomplish the job better than others, not only technologically, but also financially." One noted, "If you want to be ahead, you have to know how business functions, before business comes and knocks at your door."

Scientists have to propose research that is not only aligned to the company's products and processes but has a business format. In one scientist's words, "We are part-time scientists and part-time businessmen." One scientist explained,

> Until the eighties, we spoke the language of our profession. We mostly worked with scientists and technologists. . . . Now we are speaking the language of business. We are teaming with the businesses. . . . [Our] new mission is to build a successful partnership with the businesses.

Another said, "We used to be a research-oriented company. Technology embraced all of us, including our managers. . . . Now, we emphasize business and marketing." One noted, "We are no longer dominated by technology. . . . I guess the days of business have finally arrived." Some scientists who believed that laboratories' main concern continues to be technology justified that "there is so much talk about business because [the company] is trying its best not to lose the edge."

Different laboratories have initiated different plans to incorporate business elements into research. A laboratory in computers–office machinery has launched training sessions that emphasize commercialization of research into products. As one scientist said, "All of us have to go though a formal business training. It is mandatory. We even get a certificate upon completion. The good news is that classes are not time consuming, and they are taught at the lab." Another laboratory has developed a checklist for scientists to fill out that shows when research and business are partners, when they are aligned, and when they are detached. A laboratory in electronics-communications has been holding periodic seminars or workshops aimed at developing a more entrepreneurial mindset for scientists and more appreciation for research mindset for business people. As one manager said, "I am consulting [professors] from . . . business schools to incorporate business elements into research. . . . Soon we will gather for a day or so in a resort for sharing and learning." A laboratory in chemicals-pharmaceuticals has created electronic work sites to promote conversation among scientists, R&D managers, and marketing people. As one scientist said, "We are constantly being updated on what the market for our compounds will look like in the next five years or what we need to do to pass guidelines set by the FDA [Food and Drug Administration], etc." Another laboratory has installed "TV monitors in the sitting areas . . . to update researchers on economic and legal issues." Furthermore, managers have moved their offices close to scientists for frequent free interaction.

3. Customization of Research

Business-driven research sees the needs of customers as paramount. Earlier, corporate laboratories had autonomy from the changes in technology and customer needs. Research was on one end, and the rest was on the other end. When scientists finished the research, they turned it over to the people next in the line, and this sequential arrangement of handing over continued until research reached the business unit. Scientists as well as R&D managers had little interaction with the customer. As one manager said,

> Earlier, we had created a glass wall between our research staff and representatives of the customer. . . . We rarely entertained the idea that a customer could address a technical problem. So, there was no real reason for us to interact with him.

Now, corporate laboratories are organizing their operations to accelerate and maximize customer needs that have become demanding in terms of quality, performance, and overall value for their money. As one manager said, "The only way to succeed in a competitive global environment is to have research that is centered around the customer." Another said, "We know more about our customers than they know about themselves. Would you like to know how we do this? Members of our technical staff spend almost one-quarter of their time interacting with the customer." One explained,

> If you address the problem from a technical point of view, you would not produce the quality desired by the customer. But if you address the problem from a customer point of view, you will produce the quality desired by him.

Scientists acknowledged that "we regularly interact with business groups who give us contracts." One noted, "I have jumped from theoretical physics to what customers would like the most."

The market mechanism of funding ensures that the scientists work on those projects that are important to the customer. Corporate laboratories in computers–office machinery and electronics-communications are increasingly getting research contracts from outside sources such as business divisions or sponsors. As one scientist said, "[The company] has shifted to information science just to get contracts. It is drifting away from real research in computers." Similarly, pharmaceutical companies have been shifting from prescription drugs to over-the-counter business. One scientist explained,

> [The company] has been cutting back on discovery of new drugs because it is very expensive. . . . It takes at least ten years and millions of dollars to develop a new drug. The success rate is low. . . . But, this is not the case with nonprescription drugs.

Another said, “We are spending billions on drug research, but this money is not being used to discover the viruses.” Chemical companies are directing their efforts to life sciences rather than chemicals because genetic engineering is more profitable and in demand. As one scientist noted, “We are putting our dollar to genetically modify seeds, so crops can develop resistance to the disease and become more productive.”

4. Teaming With Non-R&D Staff

The involvement of business interests from the very start means research is conducted only when interests of various groups are met. Earlier, scientists only dealt with R&D managers who were scientists or engineers by training. These managers evaluated projects for scientists, introduced scientists to others who had expertise related to the project, assigned technicians, or secured access to equipment. R&D managers were not directly involved in research since scientists had credentials and training. As one scientist said, “Our lab used to have scientific elements of the work separate from managerial elements. . . . I worked with many managers. They knew little about my research. . . . They assigned a price tag and left me alone.”

Now, there is a strong involvement of non-R&D staff including personnel from the business divisions and marketing operations in deciding research projects. Scientists are still the main actors because they actually carry out research, supply technical knowledge, conduct experiments, and have insight in research useful to business in the future. Business managers are involved because they know about the areas of application, the strengths and weaknesses of the current products, the relative position of competitive products, what is needed from the laboratory, how the developed technology would be implemented, the work procedures of workers, problems faced by operators, and materials in use. Most important, business managers are being included because they are financing research. Scientists know that “to be successful, [they have] to bring an outside manager.”

Business managers tend to have an obsession with financial success and cost effectiveness. One scientist expressed resentment: “The business of business is to make profit. This is what keeps them moving. . . . Now they are evaluating us, our work, with the same ideal. Did we produce revenue for them or not?” Another complained that “business managers are like the overhead we have to learn to live with. . . . They are basically interested in cost and profit. We are interested in developing a drug which will be profitable for the company." One scientist explained,

> Managers have to have a technical background: otherwise, they will get no respect, at least from us. All lab managers I know of have formal training in science or engineering. . . . They lost some of their technical skills once they became managers; but it is a technical manager who learned the basics of the business world. . . . Unfortunately, we are no longer dealing with technical managers. We are dealing with business managers who do not try to understand basics of research. . . . They are only good in business and politics.

One R&D manager acknowledged, "Folks in business divisions don't get excited by research or technology. . . . They measure success by finance." Another acknowledged, "Sometimes, we have to satisfy business components in filling some technical positions."

5. Results-Based Research

Market-driven R&D has shifted the focus from fundamental research toward applied R&D. Earlier, many companies supported research that dealt with the new products or processes they decided to explore. Emphasis was on fast-moving technologies of generic interest to the company and promising ideas for which technical feasibility was in doubt and risk was high. World famous laboratories at AT&T, Corning, Dow Chemical, DuPont, Eastman Kodak, General Electric, General Motors, IBM, and Xerox nurtured the costly basic research. They succeeded in making many breakthroughs, which put them on the cutting edge of new technologies, new products, and new markets.

Now, companies are cutting down on long-term and risky endeavors. Even the chemical industry, which is often called first science–based, has been cutting back on risky research and limiting experimentation because of a falling rate of innovation, flat sales, and intense competition (Achilladelis, Schwarzkopf, and Cines 1990). Industrial expenditures for development and applied research have increased at the expense of basic research (Cahners Research 1997). For instance, in 1987 constant dollars, industrial expenditures for development increased from $53,163 million in 1985 to $73,926 million in 1995; for applied research, the increase was from $16,432 million to $22,084 million for the same period. In contrast, industrial R&D expenditures for basic research in constant dollars have grown from $3,021 million in 1985 to $5,001 million in 1995 (NSF 1996, 4/10-12, 109-10).

As one scientist said,

> In the past, you could generate ideas, which would satisfy your intellectual curiosity. . . . Managers supported the work as long as they heard you believed in the technology. It worked. [X product] came out of our lab, which revolutionized [the . . .] industry. Now we are eating our seed corn.

Another said,

> We are more like fire fighters and problem solvers now than in the past, when scientists were free to pursue avenues that were more strictly research and some applied. Now it is more development-targeted business problem solving than research in a pure sense.

Another noted, “Business people don’t fund discovery research. They only think how to look good by the time the quarterly report comes out.” One explained,

> My manager keeps saying that our research is going to generate something new. . . . I don’t think this research will lead to a new product. . . . This research is mostly directed toward updating a product and testing. My manager is too smart not to know this.

Managers explained the reasons behind the decline of industrial basic research as follows: “Basic research does not address how it could be capitalized by the business.” “Long-range research for the future isn’t practical anymore. . . . The Wall Street gives little reward to basic research. Stocks don’t go up; they go down if we do not bring out the products soon.” “We simply don’t have the resources to support the speculative research. I wish we did.” “We were facing a challenge to our competitive position in the global market. . . . We have enhanced our position primarily by supporting applied and development work.” One manager generalized: “The general mood at our lab is that pure basic research should be done at universities.”

Some managers also pointed out that basic research is beginning to reemerge in their companies. In a laboratory in electronics-communications, a small subunit has been created to attract scientists to work on the emerging markets instead of developing products and processes for the existing markets. In another laboratory in computers–office machinery, scientists are given some free time to work on creative ideas on the cutting edge of their fields. Laboratories in chemicals-pharmaceuticals are reallocating resources for long-term research. One manager even said, “The company plans to abstain from financial issues until some theoretical issues have been resolved." Yet, all managers were clear that long-range research would be business driven instead of science driven, which was the case earlier.

6. Fusing Basic With Applied

Since research is being carried out in the market-pull situation, the distinction between what is fundamental and what is applied is disappearing. Traditionally, basic and applied research have been separated. Basic research is conducted to produce knowledge without any regard to commercial applications; in applied (practical or commercial) research, value is the subject of research; and in development-specific research, products or processes are designed and tested (Jansen 1995). This classification has been criticized as it neglects the economic and social determinants of scientific research activity, the role of technology in shaping science, and the nonscientific origins of many technological developments (Basalla 1988). In industry, however, there has never been a clear-cut line separating basic research from applied research; instead, basic research projects carried a technological implication interwoven with their scientific aims as well as business goals (Schmitt 1991). Yet, centralized corporate laboratories were intensively research-driven and technology-driven enterprises. They pursued a strategy of large, high-risk research projects. As one manager said, "In old days, we did not support basic research in a pure sense; but, we supported many research projects without strings attached."

Now, scientists are working on application-oriented projects. There is a constant flow back and forth between basic and applied research with business applications. As one manager said, "We work in a team. Scientists carry out research with the experts in engineering, manufacturing, and marketing. . . . We work together from the beginning till the completion of the project. We have become a melting pot in a true sense." Another said, "You would be surprised to know that our scientists, who hold Ph.D.s, go to the factory on a routine basis." Scientists acknowledged, "We don't work by ourselves. We work in a group with engineers and people from business components. They bring in their expertise to the project." One scientist said, "In my group, basic research has become applied. . . . There may be some groups where one can still separate basic from applied; but, even there, basic research is very close to becoming applied." Another noted, "Now basic research for me is why people like you would want a computer which would convert this interview to a text perhaps in your native language."

7. University Research for Industry

As companies are curtailing in-house basic, long-term research, they are relying on universities to maintain it. The academic sector is the largest site of U.S. basic research and the second largest site of applied research. It accounts for about 50 percent of national basic research expenditures and almost 15 percent of the total applied research (NSF 1996, 108-9). Earlier, academic research was insulated from the commercialized environment even though academic scientists have had a long history of depending on mission agencies for the vast majority of their research funds (Leslie 1993). Traditionally, academic scientists worked on basic and applied research, which were either curiosity-driven or relevant to their discipline. Industry, through centralized corporate laboratories, maintained its independence in research from universities. Industrial scientists researched the problems, which originated in their discipline but were relevant to the industry.

Since the 1980s, government agencies have supported academic research, which is geared to help industry (Slaughter and Rhoades 1996). For instance, the National Science Foundation, through its new Engineering Research Centers program, has increased funding for university-industry research collaboration (Berman 1990). Industry has also been involved in new university-industry research interactions, without any federal support (Mansfield 1991, 1992). Now, academic research is valued only if it contributes to the creation of products or processes for the U.S. industry. Increasingly, industry is building on basic research conducted in the university. When Bristol-Myers and Squibb merged to form a new company, they chose the location for the research center in Connecticut for its proximity to Yale and other universities. The closer links with the university bring to the industry the latest thinking on fundamental aspects of science. Since a university does not transform basic research into products or processes, industry is hoping to capitalize on the academic research. Universities are moving beyond partnerships with industry and are entering into equity arrangements to further commercialization of academic research (Feller 1990).

One manager elaborated:

> NIH [the National Institutes of Health] distributes most of its funds to universities to support medical research. . . . This research does not go beyond academic journals. . . . We are trying to build on research conducted in the universities, which by the way is funded by the government from taxpayers' money.

Another said, "We frequently invite experts from universities, listen to their ideas. If we like what we hear, we sponsor research projects." One explained,

> Developing new technologies has become very complex. You need advance knowledge from many fields: chemistry, biology, physics, and computer science. . . . University scientists have up-to-date knowledge in their fields. . . . Our lab has initiated some programs through which we get the needed knowledge from universities. So far, we have been very successful.

Scientists acknowledged that "university research has become a virtual lab for industry." One noted, "My manager likes me to monitor basic research done in the universities." Another said, "A real synergy between industry and university is going on. . . . [The company] is bringing together scientists and engineers from universities all over the world to address its customers' problems." Another said, "My academic colleagues know rather well that their knowledge can be converted into products and marketed. . . . Often, they approach me to work on joint projects. . . . Recently, my former advisor asked me to ask my manager for a consulting job."

8. Outsourcing Research Globally

Often, collaborations with the university alone are not sufficient to meet competitive demands of shorter product life cycles and faster development cycle time. Time has become a competitive weapon in the global market. Companies are extensively outsourcing their R&D to other companies, usually in foreign countries. In the past decade or so, the frequency of international multifirm R&D alliances has increased substantially, from 175 in 1977 through 1980 to more than 1,000 in 1985 through 1988 (Hagedoorn 1990). Earlier, when a company cooperated internationally with another company, they formed a separate distinct company based on equity investments and shared profits (or losses), accordingly. Now, companies are collaborating with other companies without joint equity investments. They are contracting out to foreign companies or American-owned foreign subsidiaries. Their main goal is to reduce costs and risks. For instance, U.S. software costs are about three times higher than Greece's and nearly four times higher than India's (National Software Alliance 1998, 2/16). There is a worldwide growth of scientific and engineering professionals available for companies to take advantage of.

Generally, large companies fund targeted R&D in small-specialized companies to develop new products or processes for the large company. For instance, pharmaceutical companies are increasingly funding small biotechnology companies whose innovation share has been growing at a rapid pace. Microsoft is establishing Microsoft University Advanced Technology Laboratories in three Indian sites where Windows NT source code will be provided for R&D purposes. IBM is building a major facility in Ireland as a part of IBM Technology Campus. Boeing is relying on the Japan Aircraft Development Corporation for design and manufacturing expertise of its 777 airliner. American companies' investment in overseas R&D has been increasing three times faster than investment in R&D performed domestically.

One manager proclaimed, "Our goal is to get connected with the rest of the world." Another said, "We go overseas to serve foreign markets. We want our technology to be popular among Europeans." One explained,

> I believe you are Indian. . . . We are working with some IT [information technology] companies in India. They are small in size but very fast. They work as a part of a team. They understand exactly what we need. They deliver products on time.

Scientists, however, expressed resentment: "The bottom line is that R&D abroad is displacing our own R&D. The sad thing is that we won't see the impact at least for a decade." One said, "Some time ago, [the company] handed out pink slips to at least seventy-five of my colleagues. . . . Now [the company] is lacking the expertise they need. But they are not hiring scientists. They are getting the work done in Asia."

9. Marketability in Evaluation

As corporate laboratories are teaming with business, university, and other industries to improve the products, processes, designs, and development, R&D quality is increasingly measured by commercialization, cost effectiveness, efficiency, and profitability. Nontechnical factors, along with the criterion of technical results, are playing an active role in determining quality of research. Earlier, science led to technology, and technology satisfied market needs; commercialization was based on the application of results generated in corporate laboratories. The success of R&D was measured in articles published, technical reports produced, or patents acquired. Peers on scientific and technical merits determined excellence in research. Now, business factors have been incorporated in the evaluation of research quality. Performance against the competition is a key feature.

One manager explained, "The worth of research projects has to be measured by the value they add to the [company's] products. In today's world, it is the only way." Another said, "If business components renew their contracts, then the Center did well, and scientists performed well." Scientists acknowledged, "Profitability and efficiency have become the hallmark of research and professional success." One scientist elaborated, "We are using statisticians to help us to identify the best possible combinations. . . . In the past, we had too many combinations. . . . The testing took a very long time." Another explained, "We are using computer technology to test our compounds. It is very neat. You could find out how a compound is likely to work before you actually prepare the compound. . . . You could do the testing in seconds." Most scientists noted that "research has become cost conscious." Some complained: "Business is actually grading us, our work. . . . If we meet their goals, we get a green light; otherwise, we get a red light." Few acknowledged, "The good news is that we have started paying attention to the broader implications of our research."

10. Opening Communication

As corporate laboratories are building partnerships with business, scientists are enjoying open communication with the business managers, customers, suppliers, R&D sponsors, university researchers, scientists working for other industrial and government laboratories, and scientists working abroad. Scientists from industry are assembling with all kinds of people to work on problems relevant to industry. The new form of organization, enhanced by the electronic communications, is based on a network of alliances and partnerships. Technical advances in communications have made possible a more rapid transfer of ideas worldwide. Earlier, corporate laboratories encouraged open communication through face-to-face interaction, flexibility, informality, and uncontrolled access to electronic system. But, interaction was internal to the organization. Now, scientists are interacting internally, nationally, as well as globally, out of the old industry's structure. There is a general recognition that without a network within the company as well as outside with the frontiers of science, scientists may end up losing sight of the latest knowledge in science and the changing needs of the business. Cross-functional teams are being formed rapidly as well as dissolved rapidly after the stated goals are achieved.

One scientist said, "Last month, we held a computer science conference at [the company], not at Hilton or any other hotel. . . . A few years ago, we could not think of organizing workshops or conferences right here." Another said, "There is a lot of shifting in between programs, so we get to interact with new people and establish new working relations." One acknowledged, "Our lab is highly informal. We have easy access to academia." One manager said, "There is nothing stopping our scientists from working with business people, academics, and sponsors as members of the same team." Another said,

> Our Center is physically located here. True. But we are not really dependent on our permanent physical location. Our staff regularly visits business sites, government laboratories, universities, as well as other research centers. . . . With the wonderful world of cyberspace, we are connected with outsiders in this country as well as internationally.

One informed that "in our lab, business and research managers are linked electronically to the same system to share the same information."

Conclusion

Until the mid-1980s, a scientific perspective dominated centralized corporate laboratories in high-technology industries. Corporate management and scientists in industry and academia viewed them as scientific or technology-driven companies. Corporate laboratories lacked structure, sought consensus, made bottom-up decisions, took risks, and prided themselves on scientific and technical accomplishments. Now, research is being carried out in the context of immediate business interests, and there is less emphasis on fundamental long-term research. Most research has become mission-oriented toward development, and this objective is present from the beginning. Research is conducted only when the interests of various groups including non-R&D staff are met. It is no longer the case that scientific research is conducted first and then applied. Instead, technical, commercial, and operations staff are brought together at business-unit level for product and process development. The quality of research is determined not only by technical results but by marketability and cost effectiveness. Because of contracting out R&D with universities and foreign companies, scientists everywhere are being placed more directly in the context of usefulness to industry. As boundaries between basic and applied research are dissolving and university is involved in joint ventures with industry, institutional differences between academia and industry are becoming less relevant; instead, attention is focused primarily on the problem area relevant to industry.

These features of new research cultures in industry are acquiring acceptance and are likely to become the norm in the future. Most R&D projections suggest that technology development will continue to occur increasingly outside of the United States; R&D organizations will be required to manage their activities against quantifiable business goals and objectives in the same manner as other operating functions of the company; pressures for short-term results from industrial research laboratories will continue; financial and analytical tools will be used increasingly to assess and communicate the potential rewards and risks of long-term programs; reduced support for directed basic research will continue; R&D managers will face growing challenges to retain the best employees for long-term careers in technical roles; and R&D will not be looked at in isolation from the larger activity of technology commercialization or innovation (for instance, see IRI 1997). Even with the shift in adopting business perspectives over technical ones, all companies recognize the business necessity of investing in research for the future growth.

References

Achilladelis, B. G., A. Schwarzkopf, and M. Cines. 1990. The dynamics of technological innovation: The case of the chemical industry. *Research Policy* 19:1-35.

Basalla, G. 1988. *The evolution of technology.* Cambridge, UK: Cambridge University Press.

Berman, E. M. 1990. The economic impact of industry-funded university R&D. *Research Policy* 19:349-55.

Bowman, E. H., and H. Singh. 1990. Overview of corporate restructuring trends and consequences. In *Corporate restructuring*, edited by M. Rock and R. Rock, 8-23. New York: McGraw-Hill.

Bush, V. 1945. *Science—The endless frontier.* Washington DC: Public Affairs Press.

Cahners Research. 1997. *Research & development's basic research survey.* Des Plaines, IL: Cahners.

Cauley, L. 1995. Corporate research: How much is it worth? *The Wall Street Journal*, 22 June, p. B1.

Cohen, S., and J. Zysman. 1987. *Manufacturing matters*. New York: Basic Books.

Corcoran, E. 1991. Rethinking research. *Scientific American* 265:136-39.

Dertouzos, M. L., R. K. Lester, and R. M. Solow. 1989. *Made in America*. Cambridge, MA: MIT Press.

Edelheit, L. S. 1998. GE's R&D strategy: Be vital. *Research Technology Management* 41:21-7.

Eidt, C. M., and R. W. Cohen. 1997. Reinventing industrial basic research. *Research Technology Management* 40:29-36.

Feller, I. 1990. Universities as engines of R&D-based economic growth: They think they can. *Research Policy* 19:335-48.

Graham, M. B. 1986. *RCA and the videodisc*. Cambridge, UK: Cambridge University Press.

Hagedoorn, J. 1990. Organizational modes of inter-firm cooperation and technology transfer. *Technovation* 10:17-30.

Hounshell, D., and J. Smith. 1988. *Science and corporate strategy: DuPont R&D, 1902-1980*. New York: Cambridge University Press.

Industrial Research Institute. 1997. The biggest problems technology leaders face. *Research Technology Management* 40:14-5.

Jansen, D. 1995. Convergence of basic and applied research: Research orientations in German high-temperature superconductor research. *Science, Technology, & Human Values* 20:197-233.

Jenkins, R. V. 1975. *Images and enterprise: Technology and the American photographic industry, 1839-1925*. Baltimore: Johns Hopkins University Press.

Leslie, S. W. 1993. *The cold war and American science: The military-industrial-academic complex at MIT and Stanford*. New York: Columbia University Press.

Lohr, S. 1998. IBM opens the doors of its research labs to surprising results. *The New York Times*, 13 July, pp. D1-D3.
Mansfield, E. 1991. Academic research and industrial innovation. *Research Policy* 20:1-12.
———. 1992. Academic research and industrial innovation: A further note. *Research Policy* 21:295-96.
Markoff, J. 1998. In AT&T-TCI deal, cost and logistical problem. *The New York Times*, 25 August, p. D1.
National Science Foundation. 1996. *Science and engineering indicators*, NSB96-21. Washington, DC: Government Printing Office.
National Software Alliance. 1998. *Software workers for the new millennium*. Arlington, VA: 4600 N. Fairfax Drive.
Reich, L. S. 1985. *The making of American industrial research: Science and business at GE and Bell, 1876-1926*. Cambridge, UK: Cambridge University Press.
Reich, R. 1988. *The next American frontier.* New York: Times Books.
Rock, M., and R. Rock, eds. 1990. *Corporate restructuring*. New York: McGraw-Hill.
Schein, E. 1992. *Organizational culture and leadership*. San Francisco: Jossey-Bass.
Schmitt, R. W. 1991. The strategic measure of R&D. *Research Technology Management* 34:13-7.
Schoenberger, E. 1997. *The cultural crisis of the firm*. Cambridge, MA: Blackwell.
Sheth, J. N., and S. Ram. 1987. *Bringing innovation to market: Breaking the corporate and customers barriers*. New York: John Wiley.
Sifonis, J. 1990. The impact of technology on restructuring. In *Corporate restructuring*, edited by M. Rock and R. Rock, 253-59. New York: McGraw-Hill.
Slaughter, S., and G. Rhoades. 1996. The emergence of a competitiveness research and development policy coalition and the commercialization of academic science and technology. *Science, Technology, & Human Values* 21:303-39.
Smith, D. K., and R. C. Alexander. 1988. *Fumbling the future: How Xerox invented, then ignored, the first personal computer.* New York: William Morrow.
Souder, W. E., and P. Venkatesh. 1989. Transferring new technologies from R&D to manufacturing. *Research Technology Management* 32:38-43.
Thurow, L. 1992. *Head to head*. New York: Murrow.
Varma, R. 1995. Restructuring corporate R&D: From autonomous to linkage model. *Technology Analysis & Strategic Management* 7:231-47.
Wise, G. 1985. *Willis R. Whitney, General Electric, and the origins of US industrial research*. New York: Columbia University Press.

Roli Varma is an assistant professor of public administration at the University of New Mexico. Her research interests and publications include scientists working in industry, restructuring of corporate research and development, the comparison between scientists in industry and academia, and women and minorities in science. She is also interested in science and technology issues in India.