Research, Innovation, and University-Industry Linkages

Denis J. Prager and Gilbert S. Omenn

Summary. Carter Administration actions to enhance basic research and stimulate industrial innovation have focused attention on the importance of formal university-industry cooperative relationships in science and engineering. We have examined the status of, and potential for, university-industry research consortia and research partnerships and the current and prospective roles of the federal government in stimulating such relationships.

Trends in American research and development, technological innovation, and productivity are perceived by many to threaten this country's ability to meet critical domestic challenges and to maintain our international technological and economic leadership. In comparison with the dramatic gains made by a number of other countries, innovation and productivity in the United States appear not to be faring well. The many factors that may be contributing to this comparative decline include: economic and trade policies; environmental, health, and safety regulations; tax policies and venture capital formation; federal procurement practices; direct federal support of R & D; policies governing patents and information; the regulation of industry structure and competition; and managerial philosophies and practices affecting R & D (*1*).

One of the many potential avenues to enhance basic research and stimulate industrial innovation examined by the Office of Science and Technology Policy (OSTP) is strengthening the linkages between research and innovation and between the principal institutions involved in these activities—universities and industry, respectively. Of particular interest are university-industry research consortia and research partnerships—that is, collaborative research relationships governed by a specific, detailed contractual agreement and characterized by joint planning, management, and implementation of a significant, long-term research program of mutual interest and benefit. Over the last several years, the topic of university-industry interaction often has been discussed in the broader contexts of basic research and innovation. However, in order to focus explicitly on this subject, OSTP convened a small meeting of university, industry, and government representatives (*2*) to obtain their perspectives on the status of, and potential for, formal university-industry research partnerships of these kinds. It is our purpose here to assess the potential for increased numbers of such relationships; enumerate the incentives for, and barriers to, their establishment; cite examples of successful consortia and partnerships; and weigh various options for federal involvement in the initiation and maintenance of such relationships.

The University-Industry Connection

The overall innovation process encompasses a spectrum of activities from basic research to commercial application and marketing. For the innovation process to be productive, the generation of new knowledge and the translation of that knowledge into commercial products and services must be linked. Such linkage depends on close interaction between those who perform basic research and those for whom the results of basic research are the raw materials for product development and commercialization. Because a major share of basic science is done in the universities and colleges, whereas technological development is lodged primarily in industry, strong university-industry relationships can enhance the basic research-innovation linkage (*3*). Historically, academia and industry had a productive relationship, each helping to support the other's mission. However, the links between universities and industries weakened in the two decades following World War II, approaching their lowest point in the early 1970's. Smith and Karlesky (*4*, p. 62) have identified three principal factors underlying this decline.

1) The separation of academic research from perceived industrial needs. This separation came as a result of the increasing role of the government in science and technology, stimulated first by World War II and then by Sputnik. With the federal government supplying the major portion of available research funds, universities had much less incentive to establish, or strengthen, ties with industrial firms.

2) The decreased interest among university graduates in industrial research careers. With the availability of federal funds for academic research and education, more and more graduates eschewed industrial careers for faculty appointments, and graduate training programs became oriented toward careers in academic research. Industrial research was judged to be too applied and industrial research positions viewed as second-rate.

3) Industry's diminishing role in basic research. The industrial share of basic research spending declined steadily between 1955 and 1972, and the proportion of in-house R & D budgets allocated to basic research dropped dramatically after 1966 (*5*, *6*). Since the key to effective interaction between universities and industry was scientist-to-scientist contact on research matters of common interest, the gradual decline in industrially performed basic research decreased such contacts and impeded university-industry relations.

As a result of these and other factors, there has been a marked decline in the linkages between academia and industry. This decline may be a contributing factor to the erosion of the innovation process because it impedes the kind of two-way communication that influences the direction of research and facilitated its practical application. Such separation also complicates research that falls between pure, basic science and applied R & D. This research is conducted with an eye on ultimate application and is critical for major technical advances in many fields.

Dr. Prager is Senior Policy Analyst and Dr. Omenn is Associate Director for Human Resources in the Office of Science and Technology Policy, Executive Office of the President, Washington, D.C. 20500.

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Incentives for Enhancing the University-Industry Connection

Universities have a number of motivations for reassessing their ties with industry. There is a growing research interest in solving critical domestic problems and a renewed appreciation for the role of industry in such problem-solving. However, the primary motivations are more pragmatic. Academia finds itself being squeezed by its major research sponsor—the federal government. Competition for federal research funds has dramatically increased as inflation has eroded the purchasing power of the research dollar and increasing numbers of young scientists have sought support for their work. At the same time, government regulations related to scientific and financial accountability, human and animal experimentation, biohazards, and affirmative action have reduced the efficiency, flexibility, and independence of the academic scientist. This situation is aggravated by declining student enrollments and by decreasing employment opportunities in academic and government research centers. For these reasons, university faculty and administrators are beginning to look to industry as a source of research support, as a potential employer of advanced degree graduates, as a source of part-time faculty, and as a focus for major continuing education programs. Perceived benefits for universities include the potential for long-term research support less entangled in red tape; help from industry in making new knowledge and technology commercially useful; broader educational experience, industrial exposure, dissertation topics, and potential employment opportunities for students; and stimulation of university faculty through interaction with industrial scientists and engineers and through access to specialized industrial equipment.

Industry's incentives are equally compelling. American industry is facing stiffened competition at home and growing challenges abroad. New science-based technology is required by industry not only to meet these challenges but also to satisfy environmental, health, safety, and efficacy regulations economically. Academic institutions, with their broad array of disciplinary capabilities and research interests, represent a scientific resource that can enhance industrial research efforts (*3; 4*, p. 65). Potential benefits for industry include additional sources of ideas, knowledge, and technology on which to base potential new products and processes; ability to draw upon competent scientists from around the country without expanding in-house capabilities; high benefit to cost ratio when compared to building an in-house research unit; source of potential research employees sympathetic to industry needs; and stimulation of industrial scientists and engineers.

The country as a whole would benefit from improved substantive relations between universities and industry. Innovation should be significantly accelerated by reestablishing the role of market motivation in stimulating research and in enhancing the linkage between the development and application of new knowledge. Furthermore, the strengthening of both the academic and industrial sectors would enhance the quality and relevance of research, the stability and robustness of the research enterprise, the breadth and problem-solving capabilities of university graduates, and the competitiveness of the U.S. industrial sector.

Barriers to Enhancing the University-Industry Connection

Academic institutions are in the business of education and training. Therefore, university research is necessarily oriented toward the educational experience and the extension of fundamental knowledge. University research seldom is directed at new commercial products or processes, although it may be the basis of innovation. The emphasis is basic science and engineering, not development and commercialization. The time frame for obtaining and reporting results is long-term; freedom of communication and publication is at the heart of the academic research process; and intellectual independence is paramount. Industrial research, in contrast, normally looks to development and commercialization of new and improved products, processes, and services. Because competitive edge is critical to the success of a commercial venture, patents are important and the results of research often are proprietary and may not be published (*4*, p. 65; *7*).

There are also institutional barriers. Management philosophies, for example, differ greatly. Industry is responsible to its stockholders; its bottom line is financial viability and profits; the goal of its research is new, improved products. Industry research is run by upper management in direct support of the company's interests; management sets objectives and directs the research. Universities present themselves to "the public"; their bottom line is represented by number and quality of students and research productivity. University research is conceived and conducted by researchers; the university provides facilities and a supportive environment.

Industrial firms face a further dilemma when considering the support of university research: in-house versus extramural research. Corporate managers must be able to explain why they chose to commit research funds to an outside institution rather than build or maintain an in-house research capability which the company could more easily control and which might appear to be more cost-effective. Under what conditions is such an external commitment justified? Three were suggested by the participants in our meeting (*2*): (i) when outside assistance is required to maintain leadership in an existing product line, (ii) when the company needs "cutting edge" science to develop new leads in an existing line, and (iii) when management wishes to pursue research in wholly new product lines.

Another barrier to establishment of major university-industry research partnerships is uncertainty. The stakes are high and so are the risks. Time and dollar costs are significant and the magnitude of the potential payback is highly speculative. Also, the time period may exceed the tenure of the scientists and managers who thought the partnership was such a good idea. Both universities and industrial firms are basically conservative. Universities are reluctant to enter into long-term, detailed agreements with industry for fear of compromising academic freedom and jeopardizing federal funding of related research (*8*). Industries respond to increased governmental regulations and changing economic conditions by focusing their limited resources on "defensive research," that is, research resulting in incremental changes to existing products, process innovation to increase productivity and decrease production costs and time, and development of cost-effective ways to meet environmental, health, and safety regulations.

These relatively tangible differences between the academic and industrial sectors are magnified by attitudes that exaggerate the differences, inhibit meaningful communication, and impede attempts to form cooperative arrangements. Academicians often disdain the profit orientation and distrust the motives of industry. Some seem to believe that all industrial research is applied product development; that the competence of industrial researchers and the quality of their research is inferior; and that university-industry interaction means industry direction of university research, applied research only, lower standards of quality,

no publications, only proprietary work, and no real interaction (that is, industry supplies the money, university supplies the brains). Conversely, university research is viewed by industry as ivory-tower with little thought to applicability and too much reliance on the cumbersome publications process. Industry often finds university graduates to be too theoretical and unable to make the transition to the more applied orientation of industrial research. Such attitudes are the most difficult barriers to overcome and constitute the most significant challenge to those who believe that increased numbers of formal university-industry research relationships are desirable.

Types of University-Industry Relationships

In spite of these substantial barriers, many universities and industrial firms have established relationships which, to differing degrees, meet the diverse objectives of the two parties. In Table 1 we show relationships ranging from undirected financial gifts to significant research partnerships. In fact, a whole spectrum of university-industry interactions and relationships is possible depending on the goals and objectives of the respective organizations and their institutional characteristics. Relevant factors include: the size, structure, and profitability of the industry, the nature of its business, and the progressiveness of its research program; and the type, size, and financial health of the university, the relative size and stature of its science and engineering programs, and the orientation of its research and researchers. External factors such as geographic proximity, the location of university alumni in key industrial positions, and migration of university faculty to industry and vice versa may be very influential.

Several examples of existing relationships illustrate the diversity of potential interactions. The California Institute of Technology (Caltech) has developed several industrial associates programs. These relationships have worked out very well for both the university and the industrial firms involved. Top university scientists regularly visit industries to learn of their problems, explore scientific and technical approaches to solving those problems, and lay the groundwork for potential cooperative arrangements. This type of regular interaction, which raises the consciousness of each party with regard to the problems and capabilities of the other, is relatively common among high-technology universities. Such universities have strong science and engineering faculties, have spawned many high-technology firms within close geographic proximity, and have maintained close ties with industry.

Bell Laboratories maintains a large number of individual scientific and technical arrangements with universities around the country. These are low visibility, scientist-to-scientist, or engineer-to-engineer interactions of peers working on topics of common interest. The research is generally basic science and engineering and not proprietary in nature; publications are common and are encouraged. This kind of peer collaboration is only possible when the industrial partner has a significant, progressive in-house research capability employing accomplished scientists and engineers with acceptable academic credentials. Such capabilities are characteristic of only a few major corporations.

Research consortia provide an opportunity for a single university to relate to a number of companies in an area of science and engineering in which the university has an outstanding capability and the companies share a need for research. Member companies pay a fee to support university research of generic interest to an industry; all member companies share the results of the research. Examples of such consortia include the Carnegie-Mellon Processing Research Institute, the University of Delaware Catalysis Center, the North Carolina State Furniture Institute, the Cornell Injection Molding Project, and the MIT-Industry Polymer Processing Program.

The MIT program involves 12 member companies who pay $29,000 to $100,000 per year depending on their size and volume. A total of $560,000 supports approximately 25 projects in such areas as friction and wear of polymers, powder coating techniques, biocompatible materials, injection molding of ceramics and polymers, and nondestructive testing of composites. Most of the funds go to support graduate students. The program was started with seed funds provided through the Experimental R & D Incentives Program of the National Science Foundation (NSF). MIT staff meet often with company representatives to identify industry problems and define research needs. MIT selects the projects to be supported and provides all member companies with

Table 1. Types of university-industry relationships (*4*, pp. 65–69; *11*).

Corporate contributions to university	*Cooperative research*
Undirected corporate gifts to university fund	Cooperative research projects: direct cooperation between university and industry scientists on project of mutual interest; usually basic, nonproprietary research. No money changes hands; each sector pays salaries of own scientists. May involve temporary transfers of personnel for conduct of research
Capital contributions: gifts to specific departments, centers, or laboratories for construction, renovation, equipment	Cooperative research programs: industry support of portion of university research project (balance paid by university, private foundation, government); results of special interest to company; variable amount of actual interaction
Industrial fellowships: contributions to specific departments, centers, laboratories as fellowships for graduate students	Research consortia: single university, multiple companies; basic and applied research on generic problem of special interest to entire industry; industry receives special reports, briefings, and access to facilities, for example
Procurement of services	*Research partnerships*
By university from industry: prototype development, fabrication, testing; on-the-job training and experience for students; thesis topics and advisers; specialized training	Joint planning, implementation, evaluation of significant, long-term research program of mutual interest and benefit; specific, detailed, contractual arrangement governing relationship; both parties contribute substantively to research enterprise
By industry from university: education and training of employees (degree programs, specialized training, continuing education); contract research and testing; consulting services on specific, technical, management problems	
Industrial associates: single university; usually multiple companies; industry pays fee to university to have access to total resources of university	

briefings and reports. Projects can be characterized generally as applied R & D on problems generic to an industry and one step ahead of the current state of the art. The university owns all patents and can license member or nonmember companies. Royalties earned by MIT are shared with member companies on the basis of their yearly assessments. Publications are encouraged. MIT views this program as an excellent learning experience for students; a stimulus for faculty and students to innovate; a means of rapid technology transfer from research to application; a stimulus for broader university-industry interaction; and a means of opening up new disciplines. Industry benefits from new ideas and processes; a source of competent manpower at relatively low cost; timely assessment of current industrial practices; and having a basis for comparative evaluations of internal R & D.

The relationship most often cited as a true partnership is that between Harvard and Monsanto. Built on personal interactions spanning some 16 years, a research partnership has been established in which both parties contribute substantively to progress in a promising basic science field—the biochemistry and biology of organogenesis. As part of its long-range planning, Monsanto's management was aware of the commercial possibilities of biological research and decided to commit substantial resources to Harvard over a period of 10 to 20 years to explore and expand the field and to allow Monsanto to obtain expertise in it.

The resulting partnership is governed by a charter agreement that serves as an umbrella for a number of more specific agreements covering individual programs. Recognizing the long-term nature of fundamental research in complex systems, the agreement spans 12 years. Monsanto funds, which are used at the discretion of the university to further any specific scientific aims within the purview of the charter agreement, support Harvard personnel from several disciplines and departments. The two parties contribute equally but in different forms to the partnership. Harvard provides the conceptual scientific framework, identifies capable scientists, provides training, and controls relevant research at both Harvard and Monsanto during the research phase. Monsanto helps identify research needs, provides critical starting materials beyond the ability of Harvard to produce or buy, provides unusual and exotic analytical capabilities, and controls the development phase, providing expertise in technological innovation, development, and marketing.

The disposition of potential patents and publications is spelled out in the charter agreement. Harvard can receive royalties from either Harvard or Monsanto patents; but, in return, Harvard has waived royalties on initial sales. Monsanto controls its own inventions and receives exclusive license to all Harvard inventions in the area of cooperation for a specific period of time provided that they are progressing toward commercialization. There is no restriction on publication by either partner of its own results; the only obligation is that the other partner be informed prior to publication. The partners are in no way constrained from disclosing their own data but are constrained from disclosing information gained from the other. An outside public board advises on nonscientific policy issues.

Several features characterize this relationship. The focus of the partnership is a major new area of science of uncertain future applicability to Monsanto. The industrial partner is a substantial firm with progressive management and a highly developed research program. They do not have and do not wish to develop basic research competence in the area of cooperation. The university partner is a large, stable, productive basic research group with high interest in developing the scientific area of cooperation. The partnership evolved from long-standing personal relations between the principals.

Potentially interested corporations and university research groups that might meet the descriptions of the industrial and academic partners given above seem to us to be observing the Monsanto-Harvard experiment and examining their own opportunities with caution. We hope that such joint ventures will generate new approaches to linking basic research and innovation.

Current Federal Activities

The government already has had a significant part in bringing the academic and private sectors together. The following examples illustrate several different kinds of federal involvement.

The National Aeronautics and Space Administration (NASA) and the Department of Defense, through their major technology development and procurement programs, have stimulated the formation of research consortia to direct their collective capabilities toward the solution of specific technical problems. The Department of Energy has stimulated university-industry-government cooperation in R & D related to specific energy technologies.

The Department of Commerce (DOC) enlists the aid of universities in facilitating the introduction and application of technologies designed to improve the competitiveness of industries in the international marketplace. DOC funds a university to analyze a trade-impacted industry's structure and operations and its product development, manufacturing, and marketing methods, and to identify specific weaknesses. Working with a panel of technology-oriented business experts, the university then formulates a detailed implementation plan which is presented to representatives of the industry for their consideration. To date, this process has been initiated for the steel, footwear, stainless steel flatware, industrial fasteners, consumer electronics, and mens' and womens' apparel industries.

The NSF supports university-industry centers, university-industry research projects, and small business innovation. Through the university-industry centers the NSF encourages institutional arrangements between the university and industrial communities to stimulate scientific research and technological innovation. NSF funding of these centers begins as 100 percent during start-up and phases out as industrial membership increases. At the MIT center, for example, industry support has risen from $50,000 in 1973 to more than $500,000 in 1979, when industrial partners paid the full cost of the center's program.

The NSF also supports cooperative research projects carried out jointly by academic and industrial researchers in several fields of science and engineering. The projects are investigator-initiated, focusing on fundamental scientific questions. Proposals are reviewed for scientific merit via the Foundation's regular peer review process. Funding for the university is partly from the divisions whose fields of research are involved, partly from a special account for this purpose. This program is attracting interest from a variety of institutions. For example, Bell Laboratories is working with Lehigh University on thermal convection in cavities; several computer firms are working with Caltech on design of silicon structures; Eastman Kodak and Clarkson College of Technology are investigating crystal formation in surfactant solutions; and Artisan Industries

and the University of Houston are studying the fundamental mechanics of a filtration process.

The Small Business Innovation Program at NSF funds creative, technologically high-risk, potentially high payoff research in broad topic areas identified by NSF as having high national priority. Examples of such areas include advanced production and manufacturing processes, alternative biological sources of materials, measurement and advanced instrumentation, chemical threats to man and the environment, and deep mineral resources. NSF funds are used as "preventure capital" to conduct feasibility research on the innovative idea to attract private support. In some cases, university scientists and engineers serve as consultants to small businesses participating in this program.

Facilitative federal programs such as these are proving successful and gaining acceptance as examples of the most desirable federal role in bringing about increased university-industry interaction. The government serves a stimulative short-term role, minimizing taxpayers' cost.

Promoting University-Industry Linkages

In spite of these successes, opinions are divided over the proper federal role in the initiation and maintenance of formal university-industry research relationships. Some are convinced that the government has no role and should allow universities and industry to develop relationships as appropriate. These people argue that government participation might limit the flexibility or diversity of industry-university arrangements. Others visualize a range of federal roles. At a minimum, they see the government contributing by attempting to remove disincentives to research and innovation in general. At the next level of involvement, the government could identify problems requiring research, help identify potential partners, and facilitate negotiations. A more active role would involve the government's providing start-up funds. Finally, the government could be a third partner, sharing costs with the industry and university. In this case, too large a government role could lead to federal interventions in activities that should be the responsibility of business and industry.

On the basis of this review of the status of, and potential for, formal university-industry research relationships, several means of promoting the establishment of university-industry linkages can be suggested. Many of these were addressed in the President's Industrial Innovation Initiatives announced by the White House on 31 October 1979 (*9*).

Improved communication. There is a need to accelerate contacts between university administrators and scientists and their industrial counterparts. The objectives of these contacts are to erase preconceptions; increase understanding of goals, management philosophies, and research orientations; and lay the groundwork for improved relations and potential research cooperation. The government can facilitate this process in some cases by identifying individual and institutional barriers to improved communication and by instituting specific programs (information exchange, personnel exchanges, and conferences, for example) designed to stimulate contacts and substantive interaction. Such activities should attempt to remove interinstitutional impediments and focus on scientific matters of mutual interest. Successful relationships depend on joint efforts of individuals with sufficiently strong interest and competence in a scientific question or engineering problem that institutional barriers are surmounted.

Direct federal support of research. Representatives of both the academic and industrial sections have stated strong support for the use of federal grants as seed money to facilitate initiation of new university-industry relationships. Such grants would enhance industrial support of university research programs meeting specific criteria including demonstrable university-industry cooperation. The NSF program of cooperative research projects described above is a highly successful example of such an approach. The President has announced his intention to provide NSF with $20 million of new funds in Fiscal Year 1981 to expand this program. Furthermore, NSF will work with the Department of Defense, Department of Energy, Environmental Protection Agency, and NASA in FY 1980, and with other agencies in subsequent years, to initiate such university-industry cooperative research programs. Ultimately, an aggregate program funding level of $150 million is envisioned.

In addition, the Administration intends to establish nonprofit centers—at universities or other private-sector sites—to develop and transfer generic technologies. Each of the centers will be targeted on a technology that is used in several industrial sectors and has the potential for significant technological upgrading. Each center will be jointly financed by industry and government, with the industry share increasing each year. Four centers will be established in FY 1981 at a cost of $6 million to $8 million. Three will be sponsored by the DOC and one by the NSF.

Joint federal and industry support of basic research. The federal government and the automotive industry are planning a jointly sponsored program of basic research aimed at improving fundamental automotive technology (*10*). The program will focus on nonproprietary, generic research of interest to the entire industry, developing new knowledge in such fields as thermodynamics, structures, friction and wear, and combustion. The Department of Justice has indicated that a basic research program of this kind is consistent with antitrust law. A large portion of the research will be carried out in university laboratories under joint government-industry funding; improved university-industry relations are an important anticipated benefit. This program is seen as a model for similar efforts in other industrial sectors that could benefit from increased support and conduct of research designed to lay the technology base for new generations of products and processes. Efforts are currently under way to identify additional research areas to be the focus of such potential joint efforts.

Tax incentives. Tax credits have been suggested as a way to encourage industry to increase its support of research, including research performed by university scientists. Those who argue for such credits stress the importance of R & D as a factor in economic growth, the more favorable tax treatment of R & D investments in certain foreign countries, and the desirability of increased private sector investment in R & D. However, Canada's use of tax credits has not produced the results expected; because research is the "cheapest" end of the innovation process, incentives at the later stages of the innovation process may be more effective. The Administration has agreed to examine tax policies affecting innovation when determining the overall fiscal policy for 1981.

Antitrust considerations. Many industrial leaders perceive current antitrust laws to discourage or prohibit firms from joining together in the support of research programs of common interest. They seek a change in, or clarification of, current antitrust statutes to permit, or even encourage, competing firms to cooperate in the funding of generic re-

search. The automotive research program described above may provide a precedent for such clarification.

Antitrust laws play a specific role in promoting innovation. Vigorous enforcement of these laws spurs competition and the pressure of competition is a stimulus to the development of innovations that provide a competitive edge. However, antitrust laws are often perceived to prevent cooperative activity among competing industrial firms even in circumstances where such activity would foster innovation without harming competition. Two actions have been taken that will clarify antitrust policy and should spur more cooperative research activity by industry. The Department of Justice will prepare a guide to clarify its position on collaboration among firms in R & D, and the Attorney General, the Chairman of the Federal Trade Commission, and the Secretary of Commerce will initiate discussions with industry about innovation, antitrust policy formulation, and enforcement.

Patents. Patent laws are seen as barriers to cooperation between the private and public sectors. Both industry and university representatives would like federal agencies to change their interpretation of current patent law so that exclusive licensing by industry of inventions discovered under government support would be possible. Such changes would provide an incentive for innovation by academic and industrial scientists and engineers. As part of the Administration's innovation initiatives, legislation will be sought to establish a uniform government patent policy. Title to the patent will be retained by the government, but the contractor will obtain exclusive licenses in fields of use that he specifies and in which he agrees to commercialize the invention. There will be an exception where the government determines that such a license would be inconsistent with either the agency mission or the public interest. The government would license in all fields of use other than those claimed by the contractor The government would retain march-in rights that could be exercised in the event that the licensee did not develop the patent. The Administration also supports the retention of patent ownership by small businesses and universities, the prime thrust of legislation now in Congress.

Regulatory reforms. Both industry and university spokesmen have urged the Administration and Congress to require federal agencies to assess the impact of environmental, health and safety, and accounting regulations on research and innovation. As part of his extensive regulatory reform program, the President has directed federal regulatory agencies to respond to these criticisms while meeting their regulatory responsibilities. Performance standards will be substituted for design and specification standards wherever possible; 5-year forecasts of regulatory priorities and concerns will be prepared to facilitate improved R & D planning by industry; and agencies responsible for reviewing product safety and efficacy will, to the extent possible, expedite clearance reviews of products that are the most innovative or have exceptional social benefits.

Conclusions

The time appears to be ripe for major improvements in university-industry relationships in science and engineering. Although substantial institutional and attitudinal barriers to such relationships exist, the potential benefits are sufficiently compelling to engender confidence that those barriers can be surmounted. The federal government can play a facilitative role in fostering university-industry cooperation primarily by providing incentives and removing disincentives to such interaction. Several elements of the President's industrial innovation initiatives will indeed have that effect. However, strengthening university-industry linkages—and thus enhancing the research-innovation process—will result principally from specific initiatives taken by individual universities and companies. Ultimately, progress in this endeavor will depend on substantive interaction among academic and industrial scientists and engineers whose common interest in solving specific scientific and technical problems overcomes the attitudinal and institutional barriers to university-industry cooperation.

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