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MEETING TECHNOLOGY AND MANPOWER NEEDS THROUGH the INDUSTRY/UNIVERSITY INTERFACE

An Aerospace Industry Perspective

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

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An Aerospace Industry Perspective

A Publication of
THE AEROSPACE RESEARCH CENTER

Virginia C. Lopez, Director

In Cooperation With The
Aerospace Technical Council

George D. Krumbhaar, Jr.
Consultant

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.
1725 De Sales Street, N.W., Washington, D.C. 20036

May 1983

The mission of the Aerospace Research Center is to engage in research, analyses and advanced studies designed to bring perspective to the issues, problems and policies which affect the industry and, due to its broad involvement in our society, affect the nation itself. The objectives of the Center's studies are to improve understanding of complex subject matter, to contribute to the search for more effective government-industry relationships and to expand knowledge of aerospace capabilities that contribute to the social, technological and economic well being of the nation.

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INTRODUCTION

As the nation moves deeper into the nineteen eighties, economists, political leaders and analysts, industrial managers and even sociologists probe for solutions to a threatening prospect: the United States, once considered the most invincible economic and technological entity in the world, seems unable to break away from trends that could make it a second class nation within a decade or two.

The symptoms are evident even from a simplistic reading of the U.S. economy. Industrial productivity has experienced a long-term growth deceleration since World War II. Spending on research and development relative to the gross national product has declined in the United States while it is rising in other countries. High rates of inflation have exacerbated the situation by raising costs; U.S. industries are unable to compete effectively in product areas where they once held leading positions. The growth and technological competence of aggressive manufacturing establishments in Europe and Asia have forced U.S. business into a defensive posture as foreign imports rise.

Nowhere is the situation more ominous than in the field of high technology manufacture. This is because "high tech" has been, in the eyes of many, the one area where the United States would always remain number one. Today, however, foreign competitors are well along in implementing policies that will dilute U.S. preeminence in high technology, and Americans are beginning a realistic assessment of the country's diminished scientific and technological resources.

As the United States seeks to maintain and amplify its competitive strength, attention focuses on the research and technology foundation and on the availability, adequacy, adaptability and wise utilization of its scientific and technical manpower. These are critical issues for all segments of the U.S. economy and especially for the aerospace industry, the nation's number one manufacturing exporter. Aerospace is at the leading edge of technology and its competitiveness in world markets depends upon maintaining that edge.

With this in mind, the Aerospace Industries Association (AIA), determined to take a close look at its member companies and their existing university relationships as an initial step in the process of strengthening these ties. The study that is reported in the following pages is based on information drawn from: (1) background research, plus numerous interviews with company representatives and university, government and private sector spokesmen, and (2) a formal survey of AIA member companies. It was already known that aerospace firms have had active and, in many cases, long-standing ties with universities over the years. One objective of this study was to ascertain the type and extent of these linkages. Another was to explore the effectiveness of the relationships, and to identify ways in which they might be strengthened and expanded. Finally, it was AIA's hope that it could assist in focusing attention on the nation's research and technology needs, and the fact that the means of meeting these needs is often bound to the educational roots of industry.

EXECUTIVE SUMMARY

Foreign competitors are easing the United States out of preeminent positions in numerous areas of manufacturing, and making inroads into the region long-associated with American expertise—high technology. As ways to reverse this trend are sought, two factors appear pivotal: a strong basic and applied research base, and the availability of engineering manpower that is adept, adaptable and wisely utilized to apply the fruits of this research. These priorities have highlighted the need to strengthen the interface between U.S. industry and the American university system, which performs most of the nation's basic research and provides its engineers.

The report that follows highlights four basic concerns: (1) the relationship of research and development to economic growth and international trade competitiveness; (2) the demand for engineers to meet defense and civilian needs; (3) the state of today's engineering education; and (4) changes in the government/university/industry relationship.

Industrial support of universities as a percentage of total academic R&D expenditures has declined over the last twenty years, while the federal funding role has grown. Recent declines in federal funding of university research, however, create an excellent opportunity for industry and the university to rebuild the connection. A stronger industry/university relationship is important even if current Administration basic science funding proposals do establish greater government claims on university resources. Industry and academia have needs which can best be met through more effective interaction with one another. Further, the industry/university tie can speed up the process of technology innovation to the benefit of the economy's overall growth, employment growth, productivity growth and increased price competition. The industry/university relationship also addresses important manpower-related concerns: the orientation of research to the leading edge of technology; the relevance of engineering education, and the adaptability of engineers (the manpower resource on which this report is most particularly focused) to fast-changing technological trends and opportunities.

The study that formed the basis of this report has shown that the aerospace industry has many well-established ties with academia and is actively pursuing activities covering the entire range of interface, from personal contacts to complex research consortia. A survey conducted by AIA reveals that, in 1981, 33 member companies provided universities with more than $117.8 million of funding. About 70 percent of this was estimated to have been in support of engineering and applied science programs. Table 1 presents a breakdown of funding, by broad categories. In order of the magnitude of funding, these were: program, faculty and student support; research; acquisition of university services; and gifts. More detailed information appears on p. 40.

The survey also elicited concerns relating to engineering manpower. Major concerns were: (1) availability of specialized engineers, particularly within electrical and electronic engineering and with computer science-based training; (2) the quality of B.S. degree engineers; and (3) shortage of Ph.D.s and advanced level qualified faculty to prepare tomorrow's engineers.

TABLE I

MAJOR CATEGORIES OF AEROSPACE COMPANY EXPENDITURES[a] IN UNIVERSITIES 1981 (Millions of Dollars)

	Total Funding	In Support of Engineering and Applied Science Programs
Program, Faculty and Student Support	$ 36.9	$ 27.8
Research[b]	27.9	22.7
Acquisition of University Services	20.9	12.1
Gifts	20.6	13.1
Other	11.5	8.2
	$117.8	$ 83.8

[a] Funding totals represent expenditures of 33 member companies of the Aerospace Industries Association (for information on data collection see p. 88).

[b] Includes R&D contracts, cooperative research projects, and industrial associates programs. (See breakdown of funding p. 91C.)

The industry's experience has been that "high mutual technical enthusiam," and long-term relationships are at the heart of successful company/university relations. AIA survey respondents and those interviewed recognized that, unquestionably, industry and academia have many quite different goals as well as certain common interests; this is fundamental and inherent in their varied roles. It was felt that industry should encourage and benefit from the university's primary function of education and training. Universities, on the other hand, should attempt to gear their programs to the practical needs of industry as well as toward academic/social goals. By committing themselves to solution of the most pervasive problems, industry and the university community can overcome many of the difficulties. Some can be overcome by organizational and legal devices designed to account for divergent interests; others can be surmounted by a patient working out of each party's goals.

A number of important issues that bear on the problems of interface were examined. These were:

(1) *How best to apply industry's limited resources*—Faced with the constraints of time and money, it seems advisable that all companies develop the capability to assess the resources it will invest in university relationships and match them against achievements sought within certain time frames. Some forms of interface bring quicker results and a balanced total interface would contain slower- and faster-acting forms. The right conditions, which often are within the control of the firm, influence the success of interface, and a variety of ties creates the best overall conditions for effective cooperation.

(2) *The role of the Federal Government*—Many questions have been raised about the role of the Federal Government in the industry/university relationship, usually centering on concerns that the government's role not be overemphasized to the extent that it eclipse the key role of the private sector. The government appears best suited to act where its prestige, program and financial support can have a catalytic effect on the industry/university relationship, and where private resources are insufficient for a task in which the government has a vital interest.

The extent of industry support for universities is itself influenced by the Federal Government. In the most basic sense, this occurs through incentives (or disincentives) to research and development investment. Only through an overall increased investment in R&D will a significantly strengthened relationship between industry and the universities be possible. In the case of the aerospace industry, the amount of funding available to universities may also expand or constrict relative to the amount of research and development expenditures deemed allowable under government contracts. Additionally, the government mandate that a certain percentage of federal government contract funds be set aside for small businesses could divert some funding from universities.

(3) *Responsiveness of the academic community*—The issue of academic responsiveness to industry's needs revolves around the inherent, fundamental differences in the roles of industry and academe. Universities appear to be caught in a web of constraints, competing needs, and divergent views over the directions that engineering education should take. The nation has a vested interest in seeing that the industry/university partnership is still more fruitful and yet there is some question of just how far the partnership should extend in order to ensure the continued preeminence of American technology. A national policy of heavily promoting industry/university cooperation to produce commercially exploitable technology would change the shape and complexion of American universities. Yet a new tier of collaborative structures could bridge this concern while strengthening national capabilities.

(4) *The lack of adequate information for decision making*—The truth is that authoritative estimates of the engineering supply and demand situation abound, but each contains flaws that could alter an assessment of the situation substantially. Much reliable information is anecdotal, which means that aggregate statistics are not generally available. Information on the extent of industry support of universities is not easily obtained either because of the complexity of relationships, many of them based on informal and personal ties between individuals. Both industry and academia need fact-finding apparatuses capable of functioning effectively and of exchanging information. Means must be devised as well to take full stock of the engineering manpower situation, and the ability of universities to meet national manpower needs.

A number of promising initiatives have surfaced in Congress and the Administration to address the technology and manpower problems this report addresses. State governments are showing an increasing interest in industry/cooperative activities as well and have played key roles in a number of innovative educational endeavors, their interests evolving largely from industrial development and employment concerns. Private sector attention at all levels has led to joint action agendas and to strengthened industry-wide and individual company efforts. This is only a beginning. Significant and substantial tasks remain to be tackled if the industry/university relationship is to be fully effective and make the broadest possible contribution to national research and technology capabilities.

RECOMMENDATIONS FOR ACTION

The following recommendations are clustered around three primary entries that can contribute to a solution of the technology/manpower crisis: the aerospace industry, the academic community, and the Government—both Federal and state. The recommendations are influenced by the central aspects of the problem, which has been growing for 10 years or more and must be addressed quickly. There is an imperative need to increase support of engineering programs to forestall a possible shortage of industrial engineers. The United States must:

1. Augment/support faculty;
2. Modernize engineering laboratories and research facilities at universities;
3. Raise the quality of engineering education.

Recommendations for Industry Action

1. Explore development of an industry-wide aerospace strategy on industry/university relations that would address both problems and potentials and give the issue a higher profile within the industry.
2. Explore establishment of aerospace industry science and research centers and projects at universities—on an industry/government shared responsibility basis—structured to permit involvement of many companies in support of several broad areas of interest, as well as a single generic technology.
3. Evaluate and devise, continually, new ways to bring more focus into the university interface, and introduce university interface considerations more fully into the day-to-day corporate decision making of individual firms.

Recommendations for University Action

1. Assign priority to relevance in engineering curricula; to expansion of collaborative, problem-focused research with industry; and to increasing incentives, rewards and recognition for teaching of engineers.

Recommendations for Federal and State Action

1. Advocate and encourage efforts to improve national "literacy" in scientific and technological affairs, lending the prestige of the government and—where feasible—program support to private efforts to upgrade technical education.
2. Provide greater stimulus to R&D investment by industry, eliminating disincentives to funding of university-based R&D. Only through increased overall investment will a significantly strengthened relationship with the universities be possible. Specifically, there is need to:
   - Liberalize the range of allowable expenses under the present 25 percent credit for research costs, and eliminate the incremental rule. The incremental rule is a disincentive for companies that perform a great deal of R&D but experience cyclical peaks and valleys in outlays.
   - Equalize the R&D tax credit for industry-funded R&D whether it takes place in industry, or is contracted out to a university.
   - Reimburse industry for funding of university R&D programs (UR&D).

NATIONAL CONCERNS CENTERING ON SCIENCE AND TECHNOLOGY

For centuries, universities have been built and maintained in order to pursue knowledge and provide educated leaders. Today, American universities are also seen as sources of the manpower required to sustain the nation's technological competitiveness. And they are looked to as logical vehicles for the basic research that helps advance this technology.

At the national level, leaders view the quality and quantity of highly educated manpower as one of the key determinants of a nation's productivity. At the firm level, the connection with a local university is considered important enough by many executives to substantially influence decisions concerning the location of new plants and other facilities.[1]

In short, the way industry and universities work together—i.e., the industry/university interface—is relevant to many of the considerations facing the U.S. economy today.

The Relationship of R&D to Economic Growth and International Trade Competitiveness

Events of the past 20 years have substantially eroded the American image, once taken for granted, as the world's preeminent industrial power. Balance of payments deficits, loss of international trade competitiveness, and high rates of inflation—phenomena which did not exist for the United States 20 years ago—suggest that something is wrong with the long-range course of the U.S. economy and U.S. industry.

These trends are all the more troubling because of the implications regarding the areas where the United States was thought to be invincible: science and technology. There is a peculiar irony to the prospect of the United States having to brace itself against a flood of high-technology products from abroad. The problem goes beyond the intellectual competence of U.S. scientists and engineers to the way in which their knowledge is utilized. As one observer wryly put it, "The U.S.A. runs away with the Nobel Prizes and Japan runs a favorable balance of trade." It would seem that sufficient attention is not consistently directed to the translation of research to application or, at least, not to *commercial* application.

There is no magic formula for reversing these trends, but a better understanding of the technological innovation process could lead to more enlightened approaches for overall economic growth and prosperity. There is already a considerable amount of literature linking technological innovation with economic growth. The literature points out the importance of maintaining a vigorous national research and development infrastructure. This is especially important in the case of high-technology industry, where overall growth, employment growth, and productivity growth, along with price restraint, have substantially out performed the rest of the economy.[2]

Figure 1 sets forth the linkage in the process of innovation, from the basic research stage to the point where marketable goods and services are produced. Figure 1 shows the basic-research-to-final-sales process as a continuum with benefits to industry, society and the economy at each stage. It also indicates that benefits to the user of the final product depend upon a process which had been set in motion long before the product had been marketed. Basic research, applied research, and development are necessary elements behind the marketing of price-competitive goods and services that meet human needs.

Economists have found that the relationship between basic or applied research/development and productivity and economic growth is strong and positive. Marginal rates of return for R&D spending have been found to average consistently higher than normal rates of return, according to several sector studies.[3] Over the long term, national economic and productivity growth depend heavily upon the kind of basic research performed largely at universities.[4] An authoritative study of the U.S. economy concludes that 50 percent of national growth during the period from 1948 to 1969 can be attributed to advanced in knowledge brought about by R&D.[5]

[1] U.S. Congress, Joint Economic Committee, *Survey of High-Technology Companies in the United States,* Washington, 1982.

[2] A Commerce Department study estimated that technology-intensive manufacturing industries grew 45 percent faster than other industries during 1957-73. Employment in those firms grew 88 percent faster, productivity grew 38 percent faster, and the ratio of price to unit output increased 44 percent less. U.S. Department of Commerce, Office of the Assistant Secretary for Science and Technology, *U.S. Technology Policy: A Draft Study,* 1977.

[3] Richard Kremer and Mary Ellen Mogee, "The Process of Technological Innovation in Industry: A State-of-Knowledge Review for Congress," *Research and Innovation: Developing a Dynamic Nation,* Joint Economic Committee, Special Study on Economic Change, Vol. 3 (Washington, 1980), p. 117. Mogee, "The Relationship of Federal Support of Basic Research in Universities to Industrial Innovation and Productivity," Ibid. p. 267.

[4] *Ibid.* p. 269-70.

[5] Edward F. Denison, *Accounting for U.S. Economic Growth* (Washington: Brookings Institution, 1974) p. 128.

FIGURE I

A CONCEPTUAL MODEL OF THE LINKAGES IN THE R&D PROCESS AND THEIR BENEFITS TO INDUSTRY, SOCIETY AND THE ECONOMY

	Basic Research	**Applied Research**	**Development**	**Final Sales**
BENEFITS TO INDUSTRY	Provides store of knowledge, and new ideas, for future development and innovative technology. Reduces the costs of applied R&D	Directs research toward practical application. High rate of return on industrial R&D outlays.	Refines application of technology into product which will satisfy known needs at competitive prices.	Disseminate information about product to the end user. Provide rate of return sufficient to finance continued R&D, sales.
BENEFITS TO SOCIETY AND THE ECONOMY	Improves our understanding of our surroundings.	Practical technology often forms the basis for innovations outside the industry. "Social rate of return."	Adapts known technology to meet consumer needs at reasonable prices.	Offer consumers a choice of useful products at competitive prices. Price-competitive, U.S.-made products promote domestic and economic growth, and balance of payments and price stability.

A nation's R&D effort is conventionally measured by looking at real R&D outlays (i.e, R&D spending discounted for inflation), and also by comparing R&D outlays with the total Gross National Product (GNP). This latter measure is instructive when making international comparisons since it shows the relative importance different countries place on R&D.

In the United States, where national security and space programs occupy a large part of R&D spending, statistics allow government outlays for these categories to be separated from other R&D outlays. What these statistics show is that although the United States is spending more, in real terms, for R&D than it was 15 years ago, federal R&D support has fallen, and so has the ratio of R&D spending to GNP. In comparison with other countries, the United States falls behind the Soviet Union in total (including military) R&D effort, and behind Japan and Germany with regard to civilian R&D. (See Figures 2, 3, and 4.)

In light of these international comparisons, it is not surprising that the U.S. share in worldwide R&D-intensive exports, while still impressive, has decreased.[6] The continued heavy penetration of world markets by R&D-intensive goods from other countries gives credence to the view that the U.S. lead could deteriorate further throughout the nineteen eighties. Consistent with this outlook, a 1980 study commissioned by the Aerospace Industries Association, and titled *Research and Development: A Foundation for Economic Growth*, concludes that declines in aerospace R&D will have an increasingly negative effect on this country's international competitiveness in this sector.[7]

The resolution of national concerns regarding the economy will depend in part upon the amount of resources the nation is willing to allocate to needed basic and applied research, and development. Because R&D is labor-intensive, however, and because technological innovation is generally "person embodied,"[8] the U.S. R&D effort will always be closely tied to scientific and technical manpower.

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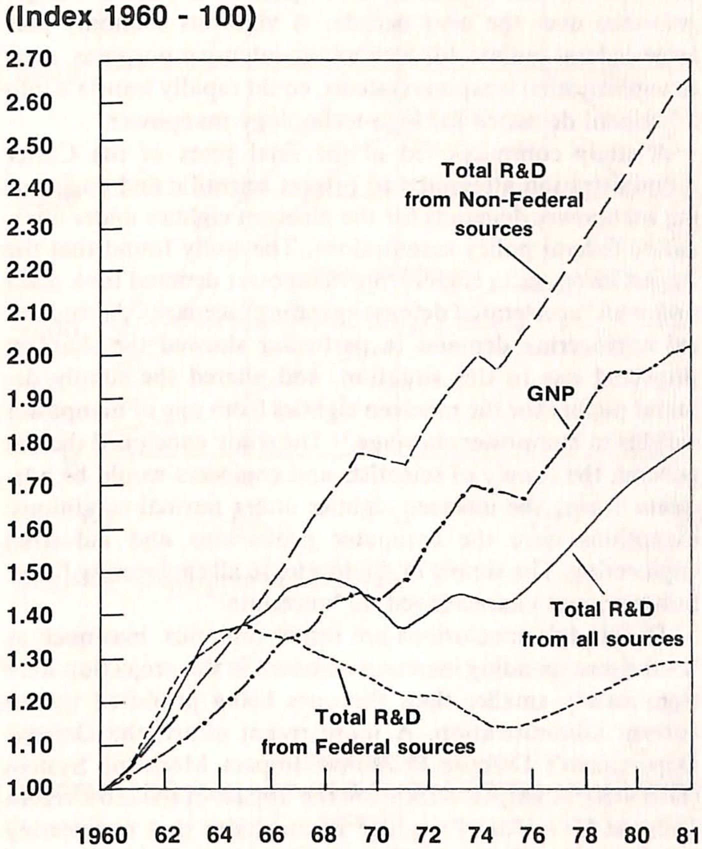
[6]National Science Board, *Science Indicators, 1980*, (Washington: Government Printing Office, 1981) p. 33

[7]Aerospace Research Center, *Research and Development: A Foundation for Economic Growth* (Washington: Aerospace Industries Association, 1980).

[8]Wages and salaries typically constitute half of total R&D outlays, the remaining half being allocated between materials/supplies and overhead (which also includes a manpower component). National Science Foundation, *Research and Development in Industry, 1977* (Washington: Government Printing Office, 1979).

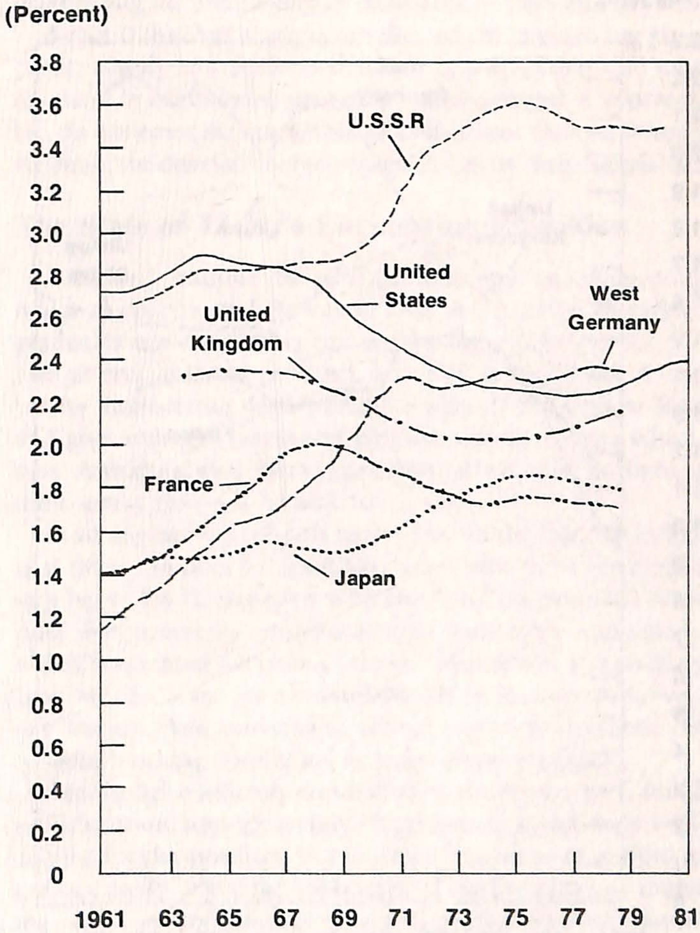
A number of studies, covering both the United States and other industrialized countries, concludes that the most efficient form of technology transfer is through the movement of knowledgeable people. See, e.g., Organization for Economic Cooperation and Development, *The Conditions for Success in Technological Development*, (Paris: OCED, 1971); National Academy of Science, *Applied Science and Technological Progress: A Report to the Committee on Science and Astronautics of the U.S. House of Representatives*. (Washington: Government Printing Office, 1967); Mogee, *op. cit; Survey of High-Technology Companies . . ., op. cit.*

FIGURE 2
RELATIVE CHANGE OF U.S. GROSS NATIONAL PRODUCT AND NATIONAL R&D EXPENDITURES
(Constant 1972 Dollars)



SOURCE: *Science Indicators, 1980,* p. 53

FIGURE 3
NATIONAL EXPENDITURES FOR PERFORMANCE OF R&D AS A PERCENT OF GROSS NATIONAL PRODUCT BY COUNTRY



SOURCE: *Science Indicators 1980,* pp. 7, 9

While the aerospace industry has vital interests relating to the broad range of scientific-technical manpower concerns, the focus in this report is on engineering manpower, which is critically important in the application of scientific and technical principles to aerospace requirements. Recently, faculty shortages in engineering schools have been perceived as a potential threat to the quality of training in this field.

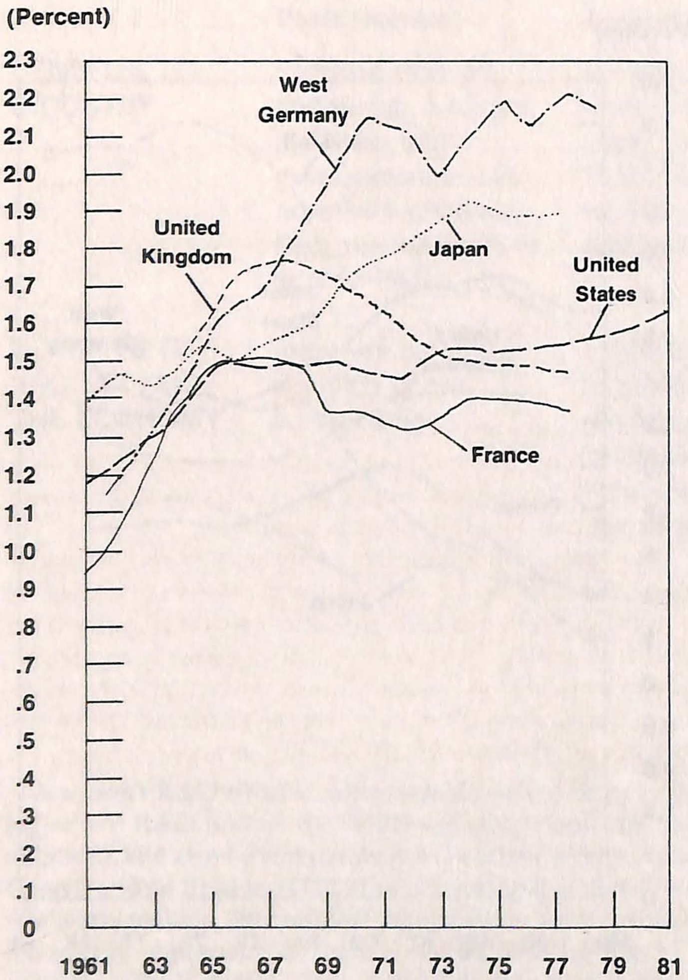
The Demand for Engineers: Defense and Civilian Needs

The labor market for engineering graduates during the coming decade will be affected by (a) existing market conditions, (b) demographic characteristics unique to the nineteen eighties and (c) federal budget priorities.

Economic indicators of labor *market conditions* imply rather tight markets for scientific and engineering personnel, in general, and engineering and computer specialists, in particular. In 1980, the unemployment rate for scientists and engineers stood at approximately 1.1 percent, compared with a rate of 7.1 percent for the labor force as a whole. The rate in 1980 for recent bachelor's and master's graduates was even lower: less than 0.5 percent. Rates as low as these can be attributed to normal job turnover, and are looked upon by economists as the equivalent of "full" employment. The utilization rate—that is, the proportion of all scientists and engineers who are employed in science and engineering—was 88 percent for all scientific and engineering fields (1980); for engineers and computer specialists, the figures were 89.3 and 94 percent respectively.[9]

[9] For unemployment and utilization rate statistics, see National Science Foundation, *Science and Engineering Personnel: A National Overview,* (Washington, Government Printing Office, 1982) p. 8-9, 40-41; also Betty M. Vetter, *Supply and Demand for Scientists and Engineers,* 2nd ed., (Washington: Scientific Manpower Commission, 1982), p. 4.

FIGURE 4
ESTIMATED RATIOS
OF CIVILIAN R&D EXPENDITURES
TO GROSS NATIONAL PRODUCTS
FOR SELECTED COUNTRIES



Perhaps the most significant *demographic characteristic* affecting the supply of educated manpower during the nineteen eighties is the decline in the number of persons graduating from high schools and entering colleges. According to authoritative estimates, this decline, which began in 1979, may result in fewer science and engineering bachelor's degrees being awarded in 1990 than in 1985.[10]

The number of doctoral degrees awarded in engineering is already on the decline. This decline started in 1973 as employers, hiring competitively in a relatively scarce market, "bid up" the starting salaries for graduates holding bachelor's degrees, and as engineering employment itself went through a downward cycle. In 1982, the average starting salary offered to bachelor's degree holders was approximately 88 percent of the amount offered to Ph.D.'s.[11] This constitutes a substantial disincentive to continuing engineering studies toward a graduate degree. One result of this is that a large percentage of the engineering Ph.D.'s in the United States is earned by foreign nationals who return to their countries after graduation. Figure 5 shows that the present output of engineering doctorates is less in the eighties than a decade ago.

The labor market for engineering graduates could also be substantially influenced by developments in *federal budget priorities* over the next decade. A vigorous economy plus large federal outlays for technology-intensive purposes, such as sophisticated weapons systems, could rapidly translate into additional demands for high-technology manpower.

A study commissioned in the final years of the Carter Administration attempted to project scientific and engineering manpower demands for the nineteen eighties under alternative federal policy assumptions. The study found that the largest increases in engineering manpower demand took place under an "accelerated defense spending" scenario. Aeronautical engineering demand in particular showed the sharpest projected rise in this situation, and altered the supply/demand picture for the nineteen eighties from one of manpower surplus to manpower shortage.[12] The study concluded that, in general, the supply of scientists and engineers would be adequate during the nineteen eighties under normal conditions; exceptions were the computer professions and industrial engineering. The supply of doctorates in all engineering fields, however, was characterized as "uncertain."

The study's conclusions are rather ominous, inasmuch as the defense spending increases assumed in the projection were significantly smaller than the ones being proposed by the current administration. A more recent effort, the Defense Department's Defense Economic Impact Modeling System (DEIMS), attempts to measure the impact of the most recent Defense Five Year Program. It concludes that engineering employment will rise significantly (by almost 16 percent) during the six years from 1982 to 1987. Within engineering fields, the most rapid growth will be in aeronautical/astronautical (25 percent) and electrical (19 percent) engineering.

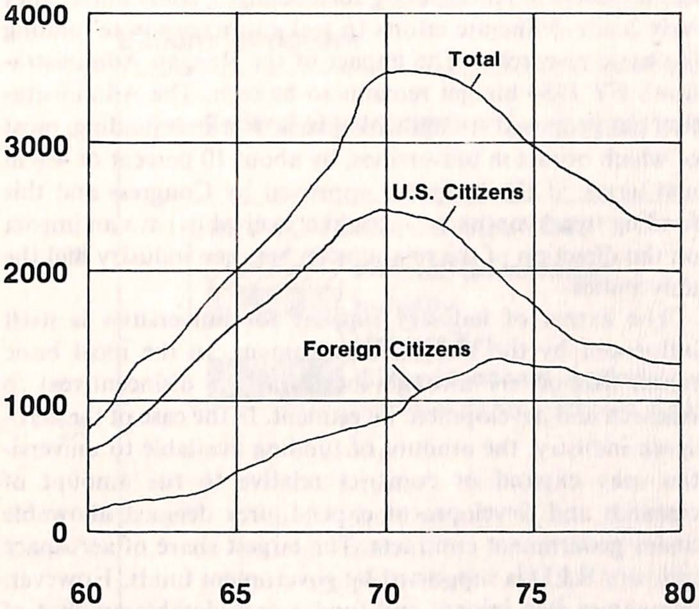
Figure 6 utilizes the DEIMS projection, along with some historical data, to show the relative condition of the engineering manpower market during the period from 1970 to 1987. The upper line of the figure traces past and projected numbers of engineering bachelor's degrees. The shaded portion represents the approximately 20 percent of past and projected new degree holders who each year choose something other than engineering employment. The "engineering manpower demand" curve takes commonly used assumptions about retirement rates, and persons entering/reentering the engineering market, to translate engineering employment into actual demand for engineers. The demand for engineers can be said to be relatively tight when it falls within the shaded portion of the graph for several years at a time.

[10] *Ibid.* p. 9.

[11] *Ibid.* citing the College Placement Council.

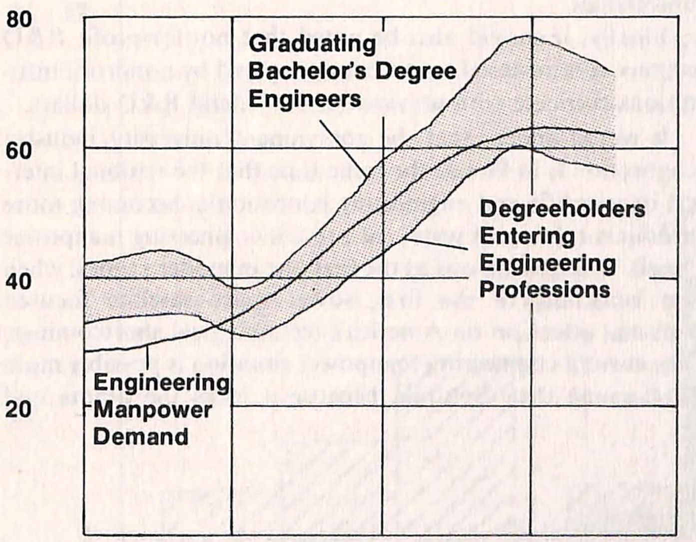
[12] National Science Foundation and the U.S. Department of Education, *Science and Engineering Education for the 1980's and Beyond* (Washington: Government Printing Office, 1980), pp. 24-34. The other scenarios examined in the study were a balanced federal budget, and a major federal initiative to develop synthetic fuels. The baseline assumptions included a gradual decline in unemployment and a small increase in labor productivity.

FIGURE 5
NUMBER OF U.S. ENGINEERING DOCTORATE RECIPIENTS



SOURCE: Department of Defense

FIGURE 6
SUPPLY AND DEMAND FOR ENGINEERING MANPOWER
1970-87



SOURCES: Scientific Manpower Commission, Department of Defense, Bureau of Labor Statistics

What Figure 6 shows is that the demand for engineering manpower, which was slack during the first half of the nineteen seventies, started to pick up in the latter half of that decade and remained relatively tight to 1982. It will remain so through the middle of the nineteen eighties, and could become tighter if there is an expected fall off in the number of engineering bachelor's degree recipients in 1986 and beyond.

A factor that has always complicated the engineering manpower supply and demand situation is that students do tend to enroll in engineering programs when demand is apparent, but do not enter the marketplace until at least four years later. At times, the demand for their specialty has by then diminished.

The State of Today's Engineering Education

A limited number of persons choosing an engineering major at college, and the career choices perceived by college graduates are constraints on engineering manpower supply. Just as crucial to the problem, however, is the ability of university engineering departments to absorb the student load and give undergraduates and graduates an up-to-date education. Anecdotal evidence suggests that all schools throughout the country may not be able to do so.[13]

Most engineering schools must live with the fact that industrial firms can offer substantially larger salaries to the limited number of Ph.D. engineers who also form the potential labor pool for university professorships. Expensive equipment, which is essential for state-of-the-art instruction at university laboratories, is simply not available given the average university budget. And universities cannot normally duplicate the modern working conditions of large industrial firms.

According to a survey conducted by the American Council on Education, approximately 10 percent of all full-time engineering faculty positions in the United States were unfilled at the beginning of the fall 1980 term.[14] The same survey found that most engineering schools had experienced substantial difficulty attracting and retaining competent faculty. Most of the schools in this position believed that the quality of their research and instruction had also declined.[15] As a result, in a number of high-technology disciplines, industry research has advanced beyond that performed in average university laboratories. Many industry officials would assert that the path of technology transfer disciplines is from industry to universities, and not the other way around.[16] However, in many cases, such as biotechnology, Very Large Scale Integration (VLSI) artificial intelligence and robotics, universities are recognized as the leaders.

The problems of obsolete laboratory equipment and faculty shortage are certainly factors in whether or not universities

[13] Jeremy Main, "Why Engineering Deans Worry a Lot," *Fortune*, January 11, 1982, p. 84; also *Science and Engineering Education*. . ., op. cit., pp. 35-37.

[14] Frank J. Atelsek and Irene L. Gomberg, *Recruitment and Retention of Full-Time Engineering Faculty, Fall 1980*. Higher Education Panel Reports No. 52 (Washington: American Council on Education, 1981).

[15] *Ibid.* pp. v, 8, 12.

[16] Survey of High-Technology Companies. . ., *op. cit.*

can supply adequate numbers of engineers trained in state-of-the-art methods and equipment. An additional concern—whether engineering schools pay adequate attention to the problems of industry—was voiced by some of those interviewed for this report; they included respondents from both industry and universities.

Here, the issue goes beyond merely the dichotomy of the theoretical versus the practical approach to problem solving. In the United States today, it also has a good deal to do with who funds the various stages of R&D, and who performs it. Figure 7 sets forth the relationships of the funding sources and the performers for basic research, applied research and development for the year 1979. It shows that universities, which conduct the bulk of the nation's basic research, depend heavily upon the Federal Government for research funding. The Federal Government supplied 75 percent of all university basic research outlays in 1979, and almost the same percentage of university total R&D outlays. By contrast, industry support of university research amounted to 2.4 percent (basic research) and 2.5 percent (total R&D). More than 60 percent of federal support for basic research goes to universities and and university-based research centers. Industry, on the other hand, has consistently spent 10 percent or less of its basic research budgets on university campuses.

According to some observers, the heavy federal involvement in university research has steered university interests toward government, rather than industry, concerns.[17] The result has been an "isolation" of industry management from university concerns, and decreased interaction of industrial firms and universities over the past 20 years. Now, changes in the government/university relationship present the opportunity to rebuild the industry/university tie.

Changes in the Government/University/Industry Interface

The government/university relationship has not been an unmitigated blessing. Federal regulations and paperwork requirements have proven to be an onerous burden on research efforts. Differential rates of federal funding have influenced the supply of researchers in particular fields, without regard to university goals. And the history of federal R&D funding will show that its stability cannot be taken for granted.[18]

In recent years, Congress has appeared to be looking for ways to reduce the heavy reliance of universities on federal budget outlays.[19] Several initiatives that would have added to the number of federal/university programs have been cut back or not funded. These dramatic changes in federal/university relations have had a profound impact on the universities themselves. Anticipating such changes, some universities have made deliberate efforts to seek more corporate funding for basic research.[20] The impact of the Reagan Administration's FY 1984 budget remains to be seen. The Administration has proposed strengthening basic research funding, most of which occurs in universities, by about 10 percent or 4% in real terms. If the budget is approved by Congress and this funding trend continues, it could conceivably have an impact on the direction of the relationship between industry and the universities.

The extent of industry support for universities is itself influenced by the Federal Government. In the most basic sense, this occurs through incentives (or disincentives) to research and development investment. In the case of the aerospace industry, the amount of funding available to universities may expand or constrict relative to the amount of research and development expenditures deemed allowable under government contracts. The largest share of aerospace industry R&D is supported by government funds. However, companies also initiate and fund a considerable amount of R&D, much of which is highly innovative and which contributes both to the company itself (by enhancing its competitiveness) and to the nation (through applicability to civil and defense needs). Over the years, aerospace companies have recovered a percentage of these research and development costs in sales—largely defense sales—of goods and services to the government.

The Small Business Act of 1982, by legislating that industry set aside a certain percentage of federal government contract funds for small businesses may also divert some funding from universities.

Finally, it should also be noted that not-for-profit R&D centers administered by both industry and by nonprofit institutions compete with universities for federal R&D dollars.

It would appear that the government/university/industry connection is in flux at the same time that the national interest in scientific and engineering education is becoming more prominent. In some ways, the present engineering manpower "crisis" is as portentous as the first one in modern times, when the launching of the first Soviet space satellite focused national attention on America's technological shortcomings. The current engineering manpower situation is possibly more threatening than Sputnik, because it lacks the drama and

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[17] U.S. Congress, House, Subcommittee on Science, Research and Technology of the Committee on Science and Technology, *Summary of House and Senate Hearings on Government-University-Industry Relations*, 96th Congress, 2nd Session, 1980, p. VIII.

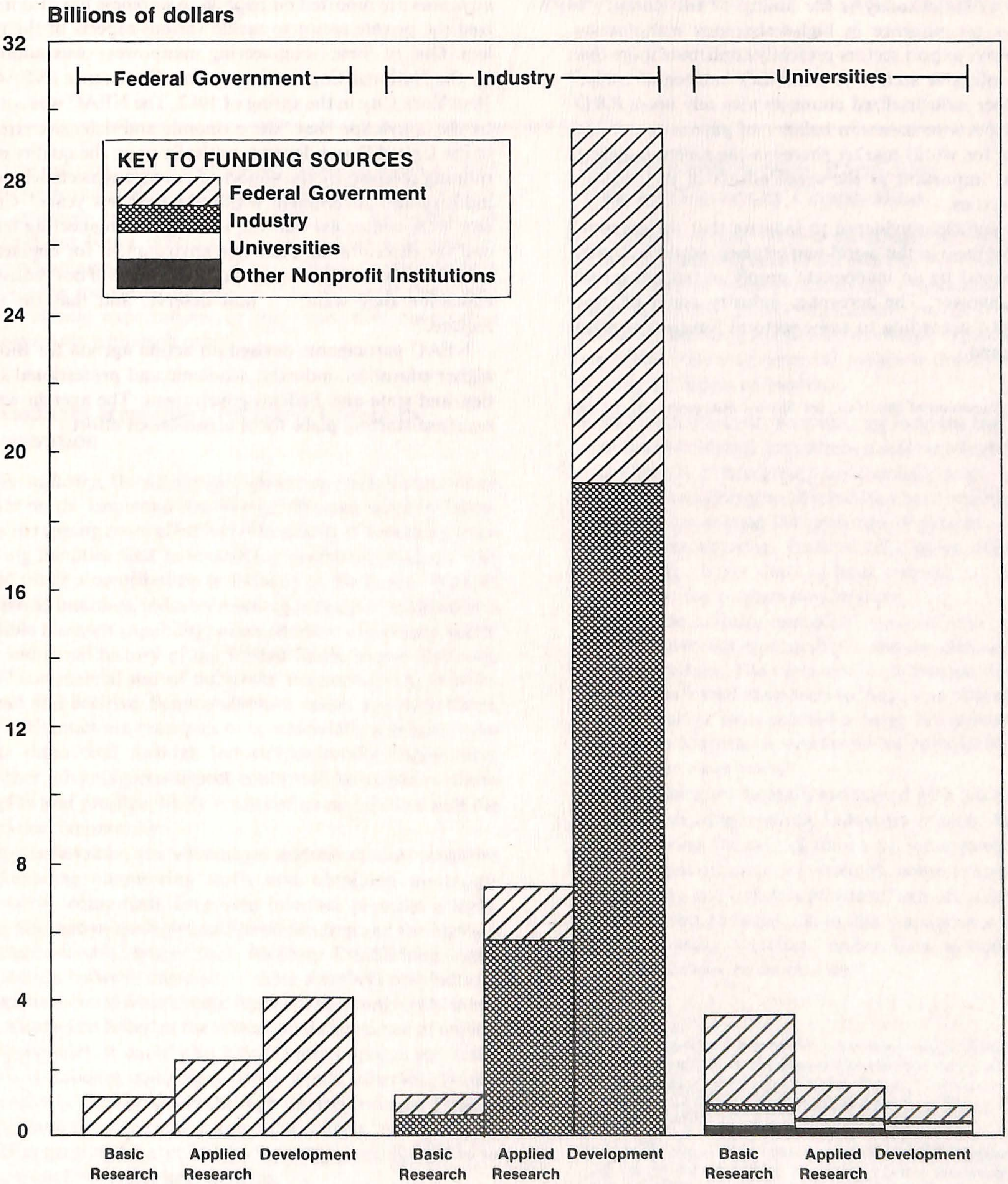
[18] For a discussion of federal regulation of universities see Timothy B. Clark, "Universities Give Administration a 'C' In Its Campaign Against Regulation," *National Journal*, August 29, 1981, pp. 1549-1552. For a discussion of differential rates of federal funding, see National Science Foundation, *Science and Technology; Annual Report to the Congress*, (Washington: Government Printing Office, 1978), Chapter 7.

[19] *Ibid.*; also Harrison Schmitt, "Government Solution I: From a Republican Senator," *Professional Engineer*, March 1982, p. 12.

[20] Susan Carey, "Facing Cuts in Federal Grants, Big Schools Try to Get Research Work from Business," *Wall Street Journal*, 9 February 1982.

FIGURE 7

WHO PERFORMS BASIC RESEARCH, APPLIED RESEARCH AND DEVELOPMENT IN THE UNITED STATES, AND WHO FUNDS IT
1979



SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources, 1982*, Government Printing Office, Washington, D.C., March 1982, pp. 25-27.

attention-getting possibility of suddenly being beaten in the race for space. Those elements which fuel the present crisis are more prosaic but nonetheless crucial: possible faculty and student shortages, obsolete university laboratory equipment, and university concerns failing to dovetail those of industry.

What is at stake today is the ability of this country to continue its preeminence in high-technology manufacture. R&D-intensive export sectors presently contribute more than non-R&D-intensive sectors to America's balance of trade.[21] Because other industrialized countries also rely upon R&D-intensive exports to maintain balance of payments stability, the struggle for world market shares in the nineteen eighties could be as important as the space efforts of the nineteen fifties and sixties.

There is sufficient evidence to indicate that the country's ability to compete in the world marketplace would be significantly impaired by an inadequate supply of technologically trained manpower. The aerospace industry could be especially affected according to some sectoral forecasts of manpower demand.

[21] For a good discussion of this issue, see *Science Indicators, op. cit.,* pp. 30-34.

Awareness of the critical nature of our technology-related problems has led not only the Administration but members of Congress to action. A number of recent legislative efforts to stimulate the United States' research and technology base, and to translate R&T into innovation and productivity advances are reported on page 36. Awareness has also mobilized the private sector to tackle various aspects of the problem. One of these—engineering manpower—was addressed by the National Engineering Action Conference (NEAC) in New York City in the spring of 1982. The NEAC was spurred by the conviction that "the economic and defensive strength of the United States depends critically upon the quality of the training received by the cohort of young engineers who enter industry and government within the next few years." Conferees were concerned that the shortage of engineering faculty and the deteriorating academic environment for engineering would mean that "young men and women will not receive the education they want, ... and deserve, and that the times require."

NEAC participants devised an action agenda for those in higher education, industry, academic and professional societies, and state and Federal government. The agenda was an excellent starting place for a broad-based effort.

INDUSTRY/UNIVERSITY INTERFACE: ADVANTAGES AND BARRIERS

Both industry and university participants stand to gain from improved interface. Their differences in basic orientation, however, also suggest that there are real barriers to working out better relations. It is instructive to summarize these advantages and barriers since such a synopsis may help provide the individual universities and industrial firms with more realistic expectations as they seek new cooperative arrangements with each other.

Advantages Regarding Industry/University Cooperation

For industry, the advantages center on research and manpower needs. Improved interface could assist industry executives in tapping more effectively the talents of university engineering faculties, and in identifying promising students who could make a contribution to industry in the future. With an improved interface, industry research managers could enjoy a credible research capability, oriented more to industry needs. The industrial history of the United States shows that, over time, commercial use of university research results is widespread and decisive. Semiconductors, lasers, synthetic fibers, and antibiotics are examples of commercially successful products discovered through industry/university cooperation. Another advantageous aspect could well be public relations benefits and prestige, likely results of an association with the education community.

For universities, the advantages address current problems of financing engineering staffs and obtaining up-to-date laboratory equipment. Improved interface provides a legitimate alternative to uncertain federal funding and the burdens that occasionally attend such funding. Establishing closer interaction between university faculty members and industry researchers could compensate for the loss of university talent to industry and broaden the educational experience of university personnel. It could also significantly improve university access to modern equipment which would otherwise be too expensive to finance solely through internal sources. Finally, conspicuously successful cooperative efforts with industry could contribute to a university's prestige, and its ability to attract quality faculty and students.

Problems and Barriers Regarding Industry/University Cooperation

The obvious differences in perspective between universities and manufacturing enterprises give rise to problems in developing effective industry/university cooperation. Successful cooperative efforts involving industry and universities anticipated and worked around such problems, but an understanding of the following potential pitfalls is important for those seeking an improved interface.

- Although university research may form the basis for important technological innovation, it seldom addresses the practical needs of developing commercially viable products. In fact, university engineering faculties have customarily steered away from solving the problems of product development and manufacturing. Traditionally, universities have conducted the larger share of basic research and industry has provided for product development.
- From the industry executive's point of view, the payback from university partnership is too far into the future and too uncertain. The climate of high interest rates in recent years has forced executives to look more toward short-term gains, rather than commit a large investment to a basic research cooperative venture whose payback may not come for 10 or more years.[1]
- Universities are basically concerned with teaching students and conducting research. Industry's viability depends upon maximizing the rate of return on investment. Because of these basic differences in outlook, communication between university and industry personnel can often falter. For this reason, some analysts claim that management of the industry/university interface, rather than technology, is the greater barrier to innovation.[2]

[1]Several studies have attempted to determine empirically the time required to bring an idea from the laboratory to the end-user product stage. Their conclusions vary from 9 to 19.2 years. Mogee, "The Process of Technological Innovation in Industry: A State-of-Knowledge Review for congress, *op. cit.*, pp. 249-251.

[2]Edwin Mansfield, "The Economics of Industrial Innovation," *Technological Innovation: A Critical Review of Current Knowledge.* eds. Patrick Kelly and Melvin Kranzmerg. (San Francisco: San Francisco Press, 1978) See also Sumner Myers and Eldon E. Sweezy, *Federal Incentives for Innovation: Why Innovations Falter and Fail. A Study of 200 Cases* (Denver: Denver Research Institute, 1976). Both works are summarized in *Research and Innovation... op. cit.*, pp. 52-53, 59-60.

- Freedom of communication and publication is fundamental to the university, while industry is concerned with maintaining a proprietary hold on information. In cases where Federal Government funds also play a part in an industry/university venture, federal procurement regulations may deny the commercial firm patent rights to any technology developed.*
- Antitrust considerations also play a role in industry/university cooperation. Under present law, a research consortium created for basic research could be jointly funded by several corporations. The same consortium could not, however, concentrate upon product design and development.

Some of these problems or barriers can be overcome by organizational and legal devices designed to account for divergent interests. Other barriers can be surmounted only through a patient working out of the goals which each party seeks from the particular industry/university cooperative venture.

* On February 18, 1983, President Reagan signed a Memorandum establishing a uniform government patent policy on the disposition of any invention made in performance of a federally-funded research and development contract, grant or cooperative agreement. To the extent permitted by law, government agency policy shall be the same or substantially the same for all firms as that applied to small business firms and nonprofit organizations under Chapter 38 of Title 35 of the United States Code.

In awards not subject to Chapter 38 of Title 35 of the United States Code, any of the rights of the Government or obligations of the performer described in 35 UK.S.C. 202-204 may be waived or omitted if the agency determines (1) that the interests of the United States and the general public will be better served thereby as, for example, where this is necessary to obtain a uniquely or highly qualified performer; or (2) that the award involves co-sponsored, cost sharing, or joint venture research and development, and the performer, co-sponsor or joint venturer is making substantial contribution of funds, facilities or equipment to the work performed under the award.

POSSIBLE INDUSTRY/UNIVERSITY RELATIONSHIPS

The modes of industry/university interface range from informal personal contacts between university and industry personnel, on the one hand, to complex research consortia on the other. Between these two extremes, the modes vary substantially, as do the likely benefits to be gained and the possible barriers.

This study found that the aerospace industry presently carries out an extensive and multi-faceted university interface, covering virtually every possible form of industry/university relationship. One documented example lists 160 different projects of university interface, being carried out at a single AIA member plant.[1] The unique characteristics of the aerospace industry influence the way the university interface takes place but the existence of an active range of relationships along the entire spectrum of possibilities is beyond question.

One method for classifying these relationships is to identify the primary beneficiary of the particular form of interface. Under this classification, such activities as corporate grants would fall into the category of "industry-to-university" relationships, while consulting services provided by professors would be part of a "university-to-industry" category. A third category would describe relationships, such as cooperative research programs and research consortia, in which the substantive benefits are intended to flow both ways.

Industry-to-University Relationships

Educational Grants

Corporate grants in support of higher education totaled approximately $1 billion in 1980, according to the Council for Financial Aid to Education.[2] An estimate of the amount of grants and gifts from manufacturing firms, in terms of pre-tax net income, showed aerospace firms exceeding manufacturing firms overall in their support of universities.[3,4] The AIA survey in conjunction with this study reported that in 1981 33 aerospace companies spent $117.8 million in support of universities. This included direct grants and gifts; various categories of program, faculty and student support; research including research contracts; and the acquisition of university services. (Details of the AIA survey begin on page 38). The AIA member company expenditures represented 1.4 percent of their collective profit before tax.

In terms of dollars, educational grants of various kinds typically comprise the largest single category of corporate grants to non-profit institutions. At least one aerospace firm devotes its entire foundation activities to educational grants. The policies and procedures regarding grants depend heavily, however, on the type of grant being given. Similarly, the manpower supply potential varies according to the type of grant.

A common theme throughout the interviews for this study was the concept of "focus" and "control." In the grants area, for example, aerospace firms generally apply the same kinds of standards as they would to expenditures for manufacturing or sales operations. This is consistent with the modern approach which looks upon corporate philanthropy as a form of social investment, from which a certain return should be expected.

From the university perspective, private sector contributions are the lifeblood of the institution. Tuition payments make up a fraction of total operating and capital costs. As the extraordinary needs of the U.S. educational system run up against the limited supply of corporate philanthropic dollars, universities have come to expect corporate donors to apply strict criteria to grants applications.

The following paragraphs illustrate some ways in which aerospace firms have approached this problem, with particular regard to the manpower ramifications of educational grants.

Scholarships. The corporate interest in graduate and undergraduate scholarships is stimulated by the potential for: attracting competent manpower; associating the name of the firm with academic excellence; and promoting company-held goals such as the education of minorities. In addition, industry's sense of social responsibility has a role in the creation of this interest. For these reasons, scholarship contributions form a prominent part of corporate philanthropic activities. Eighty-five percent of the aerospace firms responding to the survey which was part of this study administered scholarship programs of some kind.

In the corporate community generally, donations for schol-

[1] Lois Jacobini, et al., "General Electric Aircraft Engine Group Support of Area Colleges and Universities," unpublished memorandum, 1981.

[2] Council for Financial Aid to Education, "Corporate Support of Higher Education 1980" (1981), p. 2.

[3] Estimate prepared by the Council for Financial Aid to Education, Letter of Hayden W. Smith, March 26, 1982.

[4] Manufacturing firms total contributions and support of education amounted to .24 percent of pre-tax net income. The estimate for the aerospace industry amounts to .26 percent of pre-tax net income. *Ibid,;* also, "Corporate Support of...," op. cit., pp. 10-11.

arship assistance have climbed in recent years. Virtually the entire increase, however, has been in the form of company-administered scholarships, rather than contributions to university scholarship funds. Aerospace firms interviewed confirmed this trend to bring better focus to scholarship programs.

A widely, though not universally, held view of scholarships downplays their role as a recruitment device. Many of the university and company personnel interviewed agreed that the chief benefits a firm derives from an undergraduate scholarship program are recognition as the sponsor and continued university ties. Spokesmen for one aerospace firm said its regular scholarship program had been discontinued several years ago, and the firm now maintains an undergraduate program only for minority engineering transfer students. The company, active in educational grants generally, administers a fellowship program for engineering graduate students. It considered these activities a better use of corporate resources. Yet the firm does not expect that scholarship recipients will necessarily choose employment with them. As one personnel officer put it, "Students who are bright enough to get these scholarships can pretty well write their own ticket. They have seen the world and don't want to be committed to one company."

On the other hand, several firms report that they administer active scholarship programs through which they successfully recruit some of their best engineering talent. One firm pointed out that many of its senior executives and ablest minds are former scholarship recipients. For this reason, the firm rates the program as a success. However, two-thirds of its scholarship recipients do not accept offers of employment.

The firm attributes this relative success to a combination of careful planning and unique circumstances. As the area's largest employer, it is known to local university engineering departments. The scholarships, limited generally to residents of the area, are for science or engineering study at a local university. Prior to each school year, those holding scholarships sign a non-binding letter of intent stating they will accept employment with the sponsor. The study program itself must be in a field directly related to the company's interests, and scholars are generally expected to accept summer employment at the company while they are undergraduates. Every effort is made to provide them with meaningful "hands-on" work in various departments. If these scholarship students subsequently accept an offer of full-time employment with the firm, they receive a higher beginning salary than other B.S. degree recipients hired by the company. The firm is also developing a restricted stock plan for those they employ.

Several aerospace firms administer specialized scholarship programs, targeted to increase the numbers of women and minorities in engineering. Scholarship funds in such cases are sometimes channeled through university engineering departments, especially when the universities themselves are active in recruiting women and minorities. In one situation, company scholarships are administered by a third party, the Educational Testing Service.

Scholarships represent a substantial outlay per person, and are thus not the vehicle for "solving" engineering manpower shortages involving thousands of students. As discussed, firms have had difficulty retaining their scholarship beneficiaries once they receive their engineering degree. On the plus side, however, is the fact that scholarships are useful for developing a name or an image of the company on campus, and for communicating to students and faculty that the sponsor is dedicated to providing meaningful work for talented graduates. In addition, scholarships also appear to be useful in achieving certain social goals, such as increasing the numbers of women and minorities in engineering. In limited instances, scholarships have been successfully used over a long period to develop a cadre of gifted engineers with management potential.

Fellowships and other graduate programs. Corporate grants to universities for the purpose of *graduate* education constitute a relatively minor proportion of total corporate funds directed toward higher education.[5] The reasons for this appear to be rooted in the experience of the early nineteen seventies, when the engineering Ph.D. glut made such grants unnecessary, and in the present hiring patterns of aerospace firms, which, on the average, take on few M.S. and only a handful of Ph.D. graduates each year. This pattern does vary, however. One firm report that 10 to 15 percent of the college graduates hired held master's degrees and five percent were Ph.D.s.

When drawing conclusions about levels of corporate philanthropic support for graduate engineering education, it is instructive to examine the constraints on such giving. Whether channeled through a foundation or expended directly from general revenues, these corporate dollars typically undergo a strict budget process, often involving the company's board of directors. Since the philanthropic grants are usually subjected to time-consuming company procedures and the graduate engineering shortage is of relatively recent origin, it can reasonably be assumed that the corporate response has not yet been fully developed. The survey undertaken in connection with this report indicates that aerospace industry support for graduate programs will increase somewhat in the future. Unfortunately, the magnitude of the problem is such that corporate philanthropy alone cannot make up for the funding shortfall. This remains the situation even though other forms of contributions (unrestricted gifts, consulting fees and research grants) provide additional assistance for faculties and graduate students. Persons who view the graduate engineering shortage with alarm assert that, as one interviewee said, "The case for supporting graduate education has gone beyond philanthropy and is now simply a matter of self-interest."

In-house programs. According to company research directors and personnel officers interviewed for this study, graduate education programs for their own employees are one of the most widely used means of "hiring" advanced degree engineers. One firm established that approximately one half of its M.S. and Ph.D. engineers had received their advanced degrees through company-sponsored programs. These pro-

[5] A 1980 survey of more than 250 manufacturing companies indicates that less than five percent of educational support funds was designated for graduate fellowships. *Ibid.* p. 17.

grams vary. Some company undergraduate scholarship programs allow the student to opt for a master's degree upon completion of the B.S. requirements. Several firms reported that they administer highly competitive M.S. fellowships and allowed employees to take one or two years off with pay for graduate study. The Ph.D. programs, in particular, are usually tailored to the special research needs of the corporation and the student. At least one firm has made a practice of hiring, and then supporting, Ph.D. candidates through the final year of their study. Two-thirds of the firms responding to the AIA survey stated that they conducted some form of tuition reimbursement program.

The reactions of personnel officers varied as to the importance of these in-house activities in meeting overall needs for graduate engineers. A more important function seemed to be that of providing employees with a means of developing new skills in response to career opportunities within the firm. This was said to be a critical feature for firms that had to keep abreast of rapidly-advancing technology, or were subject to wide variations in market conditions.

At the present time, in-house, continuing education programs provide substantial amounts of tuition support, and could conceivably represent a flexible vehicle for coping with temporary manpower bottlenecks,[6] even if they do not address the issue of faculty shortages.

Unrestricted gifts. Employee matching gifts constitute one of the largest categories of corporate support for education, exceeding by a large margin the amounts spent for scholarships/fellowships or other forms of student aid. Such gifts usually have a per employee limit (e.g., $2000) and are given to the university of the employee's choice. Therefore, there is no absolute control over which universities will benefit from the program. Many firms encourage their employees to help in alumni fund raising; the matching gift provision is an incentive for inducing greater alumni financial support. The amount of corporate matching gifts received by any engineering department will depend, in large part, upon the loyalty of the alumni and their aggressiveness in seeking contributions. The large total of corporate matching gifts and the fact that such gifts conventionally are unrestricted form a useful, if not critical, aspect of university support.

Unrestricted grants, other than matching grants, usually involve the highest decision-making body of the donor, such as the board of the corporate foundation, or the board of the corporation itself. Aerospace firms employ various methods for ensuring that the information reaching the board is sufficient for making a reasoned decision. The methods usually include input from relevant departments in various divisions of the firm. This process of securing advice from different sections was described as difficult (especially when the company had a complicated, conglomerate structure) but essential if the firm was to enjoy a focused approach to its university relations.

[6]William R. Upthegrove, *Engineering Manpower Issues: Must It Always be Feast or Famine?* Business-Higher Education Forum (American Council on Education, 1980, pp. 12-13). See also, David Breneman, "Graduate Education in Science and Engineering: Prospects and Policy Options," unpublished manuscript, Washington, 1980, p. 3.

The corporate interest in unrestricted grants grew from the corporate stake in higher education generally. Translating this interest into grants priorities requires considerable skill, and a tightly reasoned approach to philanthropy. Interviews with corporate foundation heads, research directors and directors of external affairs revealed some common considerations relating to their decision-making processes. Some of these considerations apply not only to unrestricted grants but to other types as well, such as scholarships.

One such consideration is the school's geographic proximity to the corporation and to its major customers. This appears to carry substantial weight in the decision-making process. In several cases, as an aerospace firm has been establishing plants in new locations, it has acted simultaneously to discuss with the local engineering school how the corporation might materially assist the school's operations. The local emphasis has occurred regardless of the engineering school's nationwide standing. For this reason, and because the "return" from an investment of this kind is unquantifiable, a major motive for supporting local institutions must be ascribed to good corporate citizenship. However, the advantages of developing strong engineering educational facilities close to the firm were emphasized by many corporate interviewees. A good nearby university system was seen as an important factor in attracting and retaining good employees.

Recruitment patterns also appear to have a bearing on the attention corporate grants managers will give to certain universities. Many of the personnel officers interviewed for this AIA study asserted that recruiting was easier on those campuses where the firm had a significant presence, stemming from an active support of university affairs. This presence helped generate a good reputation for the firm among the student body; in many cases, it encouraged deans and faculty members to make corporate recruiters aware of promising students, or of students with particularly relevant research interests.

Another element that figures significantly in the allocation of grants is a firm's engineering specialty (or specialties). This is the natural result of any active firm's search for promising research coming out of the nation's universities. In some instances, a large grant has enabled a firm to gain access to the university on the same basis as membership in an industrial associates program. (These programs will be discussed in the next section, "University-to-Industry Relationships.") Both corporate and university interviewees emphasized that grants are part of the process of establishing close ties with a university, which is an important element of a productive company/university interface.

Other Industry-to-University Activities. The extent of industry/university interface among aerospace firms is so large and complex as to resist categorization. Since it is often maintained by informal contacts between faculty and corporate personnel, the true extent of the involvement is never fully realized by any single office within the university or the firm. The following describe some of the miscellaneous interface activities actively engaged in by the firms surveyed for this report.

Numerous examples exist of *corporate loans of equipment*, on corporate premises, for the purpose of giving engineering students the opportunity to learn on state-of-the-art machinery. Despite the difficulties (distances, corporate use requirements) involved, this kind of arrangement is actively sought by engineering departments. *Gifts of equipment* are also widespread, and firms regularly distribute surplus property lists among engineering schools. One AIA member company has reported donation and installation of CadCam software programs to enhance university research programs and permit the teaching of interactive graphics. In 1981, aerospace firms loaned both equipment and facilities worth \$1.2 million. They also reported \$7.3 million of directed contributions for equipment as well as construction and renovation.

The aerospace firms interviewed all had stated policies encouraging staff members to offer their services to local engineering schools as *adjunct professors*. An adjunct professorship requires the employee to seek an understanding with the firm regarding extended time off, seniority protection and other pertinent aspects. In isolated cases, adjunct professors from industry have met with some resistance from the schools' faculty screening committees. Even with these complications, use of adjunct professors has grown in recent years. Because the adjunct professor approach directly addresses the problems of faculty shortages, and allows "regular" faculty members sabbatical leaves, it may become a more critical form of industry-to-university association in the future.

Policies of the interviewed aerospace firms also encourage employees to serve as *guest lecturers*. Guest lectureships often arise as a result of informal friendships between industry and university personnel. University faculty members state that the guests brought a realistic, "hands-on" atmosphere to classroom instruction, and were often needed in conjunction with some equipment loans from industry. In at least one case, a guest lectureship enabled a firm to identify several promising students who were hired upon graduation.

A reversal of the typical industry to university guest lectureship which focuses on a two-way information flow is the "targeted seminars concept" of one aerospace company. The firms holds a series of specialized technical seminars on topics of critical interest to a product group. University seminar leaders become thoroughly familiar with one segment of industry's operations and the technical challenges, thus acquiring knowledge which should be valuable in their academic roles.

Roughly two-thirds of the aerospace firms answering the survey stated that members of their engineering staffs served from time to time on *university advisory boards*. These boards are involved in such matters as curriculum design and ascertaining research needs. Additionally, they provide a forum where engineering school deans and faculty, and industry representatives, can exchange views on a variety of mutual concerns.

The issue of faculty support is seen as critical to the solution of the current problems in engineering schools. In 1981, AIA member companies offered strong support of faculty spending \$9.8 million to hire faculty consultants and endow faculty chairs. Over \$2.5 million provided full or partial support of adjunct faculty salaries, as well as sabbatical and summer employment of university personnel.

One aerospace firm called the *employment of engineering faculty* one of the most successful forms of university interface it had since close, informal ties had been established. This relationship was a continuing one throughout the academic year. At one time, the National Science Foundation administered a program of government subsidies for faculty employment of this kind but this program is not currently funded.

Another aerospace firm has approached the problem of faculty shortages by a policy of not recruiting from faculties. Instead it attempts to encourage teachers to stay in place by supplementing salaries with grants, summer employment, and consulting agreements. It is also exploring with local universities the possibility of joint hiring of selected engineering or scientific personnel; these personnel would spend part of their time teaching and part in industry.

Existing in almost every engineering school in the country, *co-op student programs* enable a student to work at a participating firm for a semester or more each year, as a part of his or her university course of study. Firms in a student co-op program pay the student during the "employment" and usually are in close contact with the student's faculty adviser regarding research priorities and standards.

At some universities, the participating firm pays a fee in addition to the student's salary, in order to cover administration costs, which include faculty visits to the firm itself. Other programs are more informally administered and depend upon personal relationships between the student's faculty adviser and the firm in question.

These programs are popular with many universities because they not only provide practical experience for the student, but they also open up space in some of the school's classrooms and laboratories. Although the acceptance rate of co-op students who are offered permanent jobs at the firms is not high, the programs are considered to be an excellent means of communicating to other students the opportunities for pursuing chosen engineering interests. Aerospace firms interviewed indicated that they each had continuing co-op prorgrams with five or more universities, which were usually selected according to geographic proximity and/or their particular competence in certain relevant research fields. Total outlays for co-op programs by those firms responding to the survey amounted to \$5.4 million.

University-to-Industry Relationships

Engineering schools have traditionally emphasized their close ties to industry. This is the natural result of the university being a center for basic research which has led to valuable industrial application. Over the years, universities have participated in some of the significant industrial advances of the century. A list of university-based, industrial products would include transistors, radar, dacron and lasers. Semiconductors, synthetic fibers and antibiotics have already been mentioned in this report.

In the post-war years, universities have developed a large number of programs designed to institutionalize the industry/university tie. Today, universities "package" services designed to facilitate industrial access to engineering research and to unique research equipment. The most extensive of these programs involve formal relationships with hundreds of U.S. and foreign firms. For example, more than one half of the country's major aerospace manufacturers belong to the Industrial Liaison Program at the Massachusetts Institute of Technology (MIT).

There are a number of generic forms of university-to-industry relationships. Although some of these relationships vary from university to university and from department to department, the basic outlines and the issues involved are relatively constant.

Industrial Associates Programs

Industrial associates programs—also known as industrial liaison programs—are usually built around a technological area in which a university has special competence. By paying a yearly fee, which can range from $3,000 to $25,000, member firms receive a variety of services related to that discipline. The services might include invitations to one or more seminars each year, ready access to the university faculty and staff, an opportunity to become acquainted with leading faculty members on an informal basis, access to a technical information inquiry facility, early receipt of published papers, preferred treatment of corporate recruiters on campus, the opportunity to license university patents, and access to the university library.

Some associates programs are built around not a technical area but an entire university department, while others (such as those at MIT and Cal Tech) have a university-wide scope. Stanford University has approximately 20 so-called affiliates programs, with some confined to divisions within departments, and others (chemistry-chemical engineering) utilizing resources from different schools.

Industrial associates programs are popular with universities, because they can be managed relatively easily and provide a convenient starting point for possibly establishing further ties with corporate sponsors. Contributions for the programs are usually significant enough to provide substantial amounts of unrestricted funds for the various departments. Some universities build a faculty incentive plan into the allocation of program-generated funds; a faculty member can "earn" money from the program for his division or research by engaging in program-related activites.[7] In at least one university, the industrial associates program provides several hundred thousand dollars annually in unrestricted departmental funds.

[7]MIT, for example, has a system of "Revenue Sharing Points," whereby 10 percent of the gross income of the Industrial Liaison Program (ILP) is distributed to qualifying faculty and staff. An telephone conversation with a corporate ILP member earns the faculty/staff member two points; a visit to a member company's location, or chairing an ILP conference, earns 12 points, etc. In 1981, a total of $460,696 was distributed by this method, with each point being worth approximately $25.50. See "The MIT Industrial Liaison Program—A Guide for Faculty and Staff" (1982), pp. 4-5.

There were differences of opinion among aerospace firms interviewed about the usefulness of industrial associates programs to the corporate sponsors themselves. Some interviewees valued the informal contacts with faculty which the programs made possible. Most of them stated that attending seminars during which research progress was discussed was necessary to prevent duplication, if for no other reason. Criticisms of the programs centered on the lack of sufficient focus, and their proliferation in recent years. One aircraft manufacturer belongs to five such programs and is seriously considering membership in three others. Another AIA member, a large, multiproduct conglomerate, belongs to 25 associates programs.

Several university officals stated that some firms (they did not identify the type of firm) did not use the associates program to the fullest extent possible. They conceded, however, that if a firm has established strong, informal contacts with a particular professor or department, it gains many of the advantages of membership in a program without having to pay the fee. One corporate observer claims that activities such as industrial associates memberships "might be described as philanthropic and (do) not result in a working connection.[8]

Faculty Consulting

Of the universities interviewed, every one had an explicit policy of allowing, or encouraging, faculty and staff to act as consultants for outside firms, one day per week. The opportunity to become consultants was said to be a substantial "fringe benefit." One engineering department head said that, from time to time, he personally encourages firms to discuss their technical needs with younger faculty members, who otherwise might not receive the exposure to outsiders. As a result, he said, virtually all of his faculty consult with industrial clients.

A National Science Foundation survey concludes that engineering faculty members spend 3.8 hours, or approximately one half day per week consulting for outside firms.[9] This translates into a total of more than 750 man-years of engineering faculty consultation engaged in every 12 months.[10] Aerospace firms paid university faculty members an estimated $5.3 million in consulting fees in one year (1981).

Consulting arrangements are usually negotiated between the firm and the faculty member, without the intervention of the university. Agreements commonly guarantee a minimum number of hours but contain a ceiling as well. Confidentiality clauses are used where proprietary information is to be exchanged.

[8]Edward E. David, Jr., "Science Futures: The Industrial Connection," *Science*, March 1979, p. 840.

[9]*Activities of Science and Engineering Faculty in Universities and Four-Year Colleges: 1978/9*, National Science Foundation, August 31, 1981.

[10]Statistics on full-time engineering faculty in the United States are available in National Science Foundation, *Academic Science: Scientists and Engineers, January 1980* (Washington: Government Printing Office, 1981) Table B-5, p. 9.

According to interviews, the most common problems with consulting arrangements arose from mutual misconceptions about the pace at which work should proceed, and the reluctance of some professors to take on work which they felt was too commercial in nature (such as product testing). Successful consulting arrangements took place in instances when the firm had enjoyed a long-standing relationship with the faculty member in question, when particular care had been spent in identifying what kind of specialized expertise and equipment was needed, and when the high priority given to the consulting was likely to last throughout the life of the arrangement.

Consulting is commonly thought of in terms of its potential for facilitating general knowledge transfer from the university to a firm. However, it can also represent a significant portion of a faculty member's earnings, and thus aid in the retention of engineering faculty. Not much is known about what effect consulting fees have on attracting, or keeping, engineering faculty at any university, but it is known that consulting fees can often run $20,000 or more per person, per year. It is no wonder that universities and engineering school administrators place considerable emphasis on facilitating these kinds of arrangements.[11]

Research/Development Contracts

Formal research contracts between universities and outside parties can take many forms. Traditional "one-on-one" research relationships with the outside sponsor contracting for a single specific research project are still widely used. (They are the vehicle by which most Federal Government-sponsored research at universities has been conducted.)

In addition, universities are increasingly turning to cooperative research programs, and other joint research arrangements involving multiple sponsors. Aerospace industry participation in such efforts has been substantial. (Cooperative research efforts of this sort are discussed later in the section on Cooperative Research and Educational Programs, and Research Consortia).

Industry-funded, contracted research is undertaken on a case-by-case basis, usually when a special corporate research need is matched by a special university basic research competence. Frequently, the intent of the sponsor is to advance the state-of-the-art or strengthen a university research capability. In such cases, the grant can sometimes qualify as a charitable contribution under current tax law. Whether the firm chooses to classify it as such may depend upon the company's internal decision making processes.

Some aspects that a firm will consider before concluding a research contract with a university include:

(1) The proximity of the university to those who will be supervising the contract;
(2) Whether the parameters of the contract can be clearly enough defined so that the research will be efficiently directed;
(3) Whether the value of confidential information generated by the research would be compromised by university publication of the research results;
(4) How much proprietary information must be shared with the university for the research to be carried out;
(5) Whether the university patent policy is in accord with corporate goals;
(6) Whether the research is likely to generate useful information even though the university can guarantee only a "best effort" toward the research goals;
(7) Whether the proposed research is compatible with university teaching goals; and,
(8) Whether contracting research with a university gives the firm enough flexibility to respond to changing federal policies.

These considerations are discussed here briefly.

The *proximity* of the university laboratories can be a significant aid in the administration of contracted research. Organizational integration of corporate research and development is one critical element of effective R&D management and, for this reason, frequent exchange with the university researchers is essential.

The *contract parameters* should ensure that the university research is a differentiable "package" that does not duplicate—but also does not diverge sharply from—in-house efforts.

Research performed at universities under conventional research contracts is public research (as opposed to consulting arrangements, which may include a confidentiality agreement). *Publication of research results* is vitally important to the functioning of the university research complex, the university's tax-exempt status, and to the professional standing of the faculty and graduate researchers. Universities will not accept research contracts if publication is not permitted, although they generally will agree to delaying publication for a limited period in order to protect patent rights.[12]

Sometimes a firm must supply *proprietary information* to university researchers in order for them to carry out the terms of the contract. The firm is allowed to review the research results prior to publication to insure that the proprietary disclosures are not reflected. Universities sometimes limit the conditions under which they will accept a contract involving proprietary information (MIT requires that the research still be meaningful for students not having access to such information[13]), and corporate research directors are reluctant to contract out work when large amounts of proprietary data are involved.

Patents generated under sponsored research at a university generally belong to the university itself, which shares royalties with the actual inventor. Licenses are normally granted to the sponsor, although the university's decision to grant an exclu-

[11] According to interviewees, engineering faculty consultants at leading engineering schools can command $100 per hour. The 3.8 hours per week in average consulting time figures out to 197.6 hours per year.

[12] See, e.g., Massachusetts Institute of Technology, Office of Sponsored Programs, *Guide to Research Agreements With Industrial Sponsors* (1982); Princeton University, *Policies With Regard to Publications and Inventions in Industrial Grants and Contracts for Research* (1960).

[13] Massachusetts Institute of Technology, *op. cit.*, pp. 15-16.

sive, or a non-exclusive, license varies from case to case. In some instances, an exclusive license might be required to develop an especially promising invention. Exclusive licenses are not normally granted for the life of the patent, but for a much shorter period, such as five to seven years.[14] Sponsors are sometimes allowed such privileges as royalty-free use of the license for a limited period of time. When research is likely to generate patentable results, a firm must seriously consider whether these traditional licensing arrangements are compatible with effective product development.

Because research is unpredictable, a university contractor cannot promise anything more than a *best effort* to complete the research within the total estimated cost. If a research project is likely to exceed the budget, the sponsor normally will have the option of receiving a report on what has been accomplished, or of renegotiating the budget.

Universities are attracted to sponsored research not only for the leverage provided by outside funding, but also because of the possibility of using these resources for advancing the state-of-the-art and *affording students thesis and research opportunities.* Some universities have explicit policies requiring contracted research to provide these kinds of opportunities.[15]

The aerospace industry is somewhat unique in that most of its basic research is government financed. Like other entities that depend upon federal financing, aerospace firms must adjust their production and research to accommodate uncertain *federal policies.* At least one contracted research project foundered because federal priorities had changed during the contract's two-year term.

Each of these considerations acts to limit an industrial research director's choices when deciding to enter into a research contract with a university. Nevertheless, frequent occasions arise within the aerospace industry when basic research needs can best be met at the university level. Aerospace firms responding to the AIA survey spent $14.5 million for sponsored research in 1981, and survey results indicate a tendency toward increased spending in this category of industry/university interface.

Contracts examined in preparation for this report were, by and large, fixed-term, fixed-price contracts consisting of a brief work statement and other negotiated language. One significant departure from this pattern is a recently concluded contract between a major aerospace company and MIT which is essentially a renewable "umbrella" contract covering a number of research projects. The advantage of this form of contract, according to company and MIT personnel, lies in saving the parties from extended legal negotiations for each contract.

This report's survey and the accompanying interviews attempted to isolate factors common to successful research contracts with universities. Findings showed that many factors which facilitate the success of such contracts are not in themselves so essential that their absence would spell failure. They also show that a unique research capability, such as specialized testing equipment, does not guarantee a successful contract. When a firm and a university department had a close relationship that spanned a number of years, with frequent interchange covering a variety of forms (industrial associates, scholarship grants), the outcome of a basic research contract was more likely to be successful. On the other hand, when each party's knowledge of the other was incomplete, difficulties were more likely to arise in the administration of such a contract.

Cooperative Research and Educational Programs and Research Consortia

Probably the most significant development in industry/university relations in recent years has been the growth of the universities' specialized centers, which are dedicated to generating close industrial interface in particular research areas. The concept is adaptable to different disciplines and organizational environments; successful centers exist utilizing quite diverse operational and financing structures. In 1981, aerospace firms spent an estimated $8.6 million in membership and other fees in these cooperative research projects.

Five such centers involving aerospace firms will be described here. Collectively, these centers illustrate the diversity of this kind of research arrangement.

The MIT-Industry Polymer Processing Program was founded in 1973 with the assistance of seed funds from the National Science Foundation. Today, it is self-supporting. Its one dozen industrial members, including two aerospace firms, pay fees ranging from $29,000 to $100,000 per year and support more than one half million dollars of research. Such projects as the research in fiber breakage and the measurement of polymer moisture content are common to the program. While these projects are chosen by the professional research staff, the direction of the research is often decided upon after consultation with industry sponsors.

The members of this research consortium, as this kind of arrangement is usually called, receive special quarterly reports on the progress of research, and have access to MIT's professional research staff and facilities. The information developed by this research is published. Sponsors have the advantage of combining their basic research budgets with those of other sponsors, in order to produce a greater amount of focused, basic research than they could accomplish singly.

The Polymer Processing Program also undertakes conventional "one-on-one" sponsored research of interest to government and/or industry sponsors. One such project—developing a heat shield molding technique for the external tank of the space shuttle—lays claim to a potential savings of $200 million over the projected life of the shuttle program.[16]

[14] *Ibid.*, pp. 16-21. Also, Virginia Polytechnic Institute and State University, *Contractual Considerations* (undated mimeo), p. 3.

[15] See Massachusetts Institute of Technology, *op. cit.*, p. 1.

[16] Massachusetts Institute of Technology, *Laboratory for Manufacturing and Productivity, Annual Report 1980-81* (1981), p. 23

The Center for Manufacturing Productivity and Technology Transfer at Rensselaer Polytechnic Institute, was founded in 1978 with the aim of "attracting, training, and directing highly motivated young engineers into the manufacturing industry to help reverse the current declining productivity growth rates in the U.S."[17] Five founding members, including three aerospace firms, have each invested a one-time fee of $300,000 or more; associate members, another four aerospace firms are included, pay annual fees (from $20,000 to $80,000) that are based roughly on a percentage of gross sales.

The approach of the center is to involve students and research directors in practical manufacturing problems, under conditions as close to those of industry as possible. Research projects are generally initiated by the sponsors themselves. They are supervised at the center by "project engineers," with industrial experience, who operate under deadlines and budget limitations as they might in an industrial research laboratory. Whenever possible, the center undertakes to see its research results through to actual implementation at the industrial site. The center also makes a concentrated effort to respect the proprietary interests of sponsors, both in the handling of confidential information and in its patent and publications policies.

Shortly after the center was founded, it adopted a policy of not accepting federal government funding, although it could have qualified for such support. This decision has generally freed the center's operations from a good deal of federal regulation. Long-range center policy is now determined by its administration, in conjunction with the founding members.

Several aspects of the center directly address the problem of engineering manpower. First, its practice orientation means that the center is developing a research capability to which industrial sponsors can look for state-of-the-art manufacturing research and additional manufacturing engineers. Second, both the center and its sponsors agree that it can offer undergraduate and graduate students exciting, hands-on experience, in a setting that will bring them frequently into contact with potential employers. Third, the center's use of project engineers, instead of faculty, for supervising research projects is intended to draw upon, and add to, industry's store of trained manpower; project engineers are to be employed for a maximum of five years, after which time they are expected to return to industry.

The U.S. Air Force recently joined with several aircraft gas turbine firms and schools of engineering to develop a ***Program for Graduate Studies and Research in Aero Propulsion Technology (AFRAPT).*** The program is aimed at encouraging recent bachelor's and master's degree recipients to pursue graduate studies before taking up permanent employment. Students who enter the program are supported by summer jobs at one of the participating firms and during the academic year, by research stipends financed by Air Force grants. Because each student enters the program at the summer job phase, the potential is there for the student to choose a graduate research program with the needs of the sponsoring firm in mind. The program allows for, and actively encourages, the use of company facilities for the students' research.

AFRAPT was started in 1982, with five corporate and three university participants. A unique aspect of AFRAPT is that it involves no extra federal funds. It is organized so that students apply to the university graduate school and the participating firm through the normal channels. The university itself negotiates the research contract on which the student may be working just as it would with other Air Force-sponsored research.

A unique state and industry-financed venture, the ***Center for Excellence in Engineering*** has been in operation for several years at Arizona State University. The center, with start-up costs budgeted at $32 million over a five-year period, is being aided by $8.5 million in unrestricted grants, equipment gifts and sponsored research from local industries, which include four aerospace firms. One of the center's conspicuous funding successes featured persuading the Arizona State Legislature to appropriate amounts for the venture. University spokesmen attribute this to the work of the center's advisory council, which includes the president or senior division executive of each of the aerospace firms that have given financial support. As one ASU spokesperson put it, "The single ingredient to our success has been the dynamic involvement on a personal basis of the advisory council with the political hierarchy of the state."

The center is on schedule with a plan to expand its faculty from 100 to 160 during its first five years. It has deliberately set high faculty salaries in order to attract quality engineering talent. The center claims to have hired full professors from industry as well as from other universities.

Although at present the center does not plan to increase student enrollments substantially, it has already raised the entrance standards. "By raising the quality of the student body, we will increase the number of students who actually graduate and go to industry," a spokesman said.

A Rotary Wing and Propulsion Center has resulted from negotiations among Sikorsky Aircraft, Avco Lycoming, and the University of Bridgeport in Connecticut. The idea for such a center, which opened in the fall of 1982, arose from the perceived need to address the rapidly developing level of required rotorcraft technology, as well as the engineering manpower shortage in rotary wing aircraft and propulsion. Students at the center are employees from the sponsoring companies with B.S. degrees and an interest in continuing their education on a part-time basis, as well as other students interested in the rotary wing and propulsion area. The center hopes to expand its capability both for students and for sponsored research.

A unique aspect of the center is the active participation of Lycoming and Sikorsky engineering staff on the faculty. Where necessary, the center draws upon them to augment its own resources in basic engineering sciences.

Several advantages promise to accrue to the sponsors of this project. By having a specialized engineering center close

[17]Rensselaer Polytechnic Institute, *Center for Manufacturing Productivity and Technology Transfer* (1981), p. 5.

at hand, the sponsoring firms will gain a convenient means for upgrading the skills of their engineering staffs. In addition, they will be creating a competent engineering center and intellectual focus for the community; surveys show these aspects to be significant in attracting both employees and new firms into the area.[18]

The local university interface appears to be more important for aerospace firms located outside the major concentrations of high technology companies (such as Route 128 in Massachusetts and Silicon Valley in California) than for firms situated within these "high tech" areas. Recruiters for these more "outlying" firms repeatedly stressed the importance of this interface as an aid in recruiting employees who would be likely to remain with the firm. The intent of the planners of the Bridgeport center is to create the kind of community asset that will be a magnet for skilled personnel and relevant research.

[18]See footnote 1, p. 9. See also Frank Coss and Marjorie Freedland, "Which Companies You Want to Work for and Why," *Graduating Engineer*, March 1982, pp. 15, 19.

The interviews for this report, plus printed sources, have isolated a number of factors that seem to have been common to the successful cooperative arrangements involving aerospace firms.[19] First, there must be strong leadership and an organizational focal point for the cooperative arrangement in order to balance the sometimes divergent interests of the university and the sponsors. Second, the aims of the industrial and university partners must be thoroughly and specifically spelled out and discussed. Third, there must be a strong mutuality of interest, which should be incorporated into public statements and literature. Fourth, there should be active support and acceptance by all the parties involved, including faculty and students.

Each of the established centers discussed here has enjoyed most of these characteristics, and thus has either become successful or has substantial promise of becoming so.

[19]This section of the report relies in part upon J.H.U. Brown, "The Research Consortium—Its Organization and Functions," *Research Management*, May 1981, p. 38; also, R. M. Colton, *An Analysis of the National Science Foundation's University-Industry Cooperative Research Centers Experiment*, National Technical Information Service (1979).

ISSUES

One conclusion that can be easily drawn from this discussion of industry/university interface is that the aerospace industry is involved in a broad and growing set of relationships with university engineering schools and departments across the country. Many of the arrangements have been dictated by circumstances of geography, the existence of specialized skills, the particular needs of the firm or university, and even the numbers of university alumni on the corporate engineering and managerial staff.

The benefits of these relationships clearly flow both ways. For involved firms, a competent engineering school can be a focal point for generating new knowledge, ideas, feedback, intellectual stimulus and bright young engineers. For the university, the array of relationship activities (scholarship programs, summer hires, sponsored research and matching grants, etc.) has the cumulative effect of strengthening the engineering department and its ability to attract excellent students.

Until recently these relationships were looked upon chiefly in terms of their potential for promoting technological innovation and, consequently, increasing productivity, along with enhancing the nation's ability to compete in the marketplace.[1] As the prospect of engineering manpower shortages has come to be better understood, analysts and administrators have looked more and more to the industry/university interface as a means of improving the quality of engineering graduates and expanding their numbers.[2]

A number of important issues bear on the relationship of the university interface to the solution of industry's various needs. These issues include how best to apply industry's limited resources, the role of the Federal Government, the responsiveness of the academic community, and the lack of adequate information for decision making. Because the focus in this study is on the industry's role, more attention is given to how companies might address the university relationship in terms of both needs and constraints. Nonetheless, the other issues must be addressed if ties between the world of industry and that of academe are to be strengthened.

Applying Industry's Resources

The economics of the interface are complex, as they vary according to the perspective of the participant. A large corporation located in the vicinity of a leading engineering school is likely to get different results from certain kinds of interface than a smaller firm located relatively far away.

Virtually all corporations, however, approach an industry/university alliance accompanied by constraints of expenditure and time. For this reason, it would be instructive to ascertain the resources required to produce returns in all of the various connections possible in an industry/university relationship—as well as the time frame within which such a response would be likely to take place. Naturally, presentation of such a volume of information in this report would be impractical but, by concentrating on only one area—manpower needs—it is possible to effect a representative view of the total resources-return picture. Figure 1 depicts the two constraints in their manpower context.

In this case, the horizontal, "time-delineated" axis would serve to distinguish forms of interface (such as adjunct faculty) which produce a more immediate response from other forms (such as unrestricted gifts) which generate a slow response. The vertical, "resource expenditure-delineated" axis would in a similar way distinguish service on advisory boards (low resource expenditure) from an undergraduate scholarship program, in which the relative outlays would be large.

Categorizing forms of industry/university interface according to this model is, of course, a subjective process. The same program may produce different responses at different firms or at different universities; various firms may gauge the "manpower response" differently, according to whether their manpower needs center on undergraduates, graduate students or faculty; and the time delineation means little without more specificity (e.g., Is two years a "more immediate" or a "less immediate" response?)

Figure 2 presents a hypothetical categorization for an average firm. For this purpose, "manpower response" is taken to mean any beneficial engineering manpower effect, whether

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[1] See, e.g., *Summary of House and Senate Hearings..., op. cit.*, which cites the aim of the hearings as "improving those (government-industry-university) linkages for the purpose of making society more innovative and productive." p. VII. See also "Increasing the Contribution of Engineering Education to Manufacturing Productivity," *Proceedings of the Industry-University Conference on Productivity Improvement* (Provo, Utah: March 1978), sponsored by the National Center for Productivity and Quality of Working Life; also Neal H. Brodsky et al., *Industry/University Cooperation: A Preliminary Analysis of Existing Mechanisms and Their Relationship to the Innovative Process*, New York University Center for Science and Technology Policy (1980).

[2] "Government-Industry-Academia: Engineer Shortage Sparks a Once-Unlikely Merger," *Washington Post*, 27 December, 1981, p. L1.

FIGURE 1

A CONCEPTUAL FRAMEWORK FOR ANALYZING THE COMPARATIVE EFFICIENCY OF CERTAIN FORMS OF INDUSTRY/UNIVERSITY INTERFACE, IN SOLVING ENGINEERING MANPOWER SHORTAGES

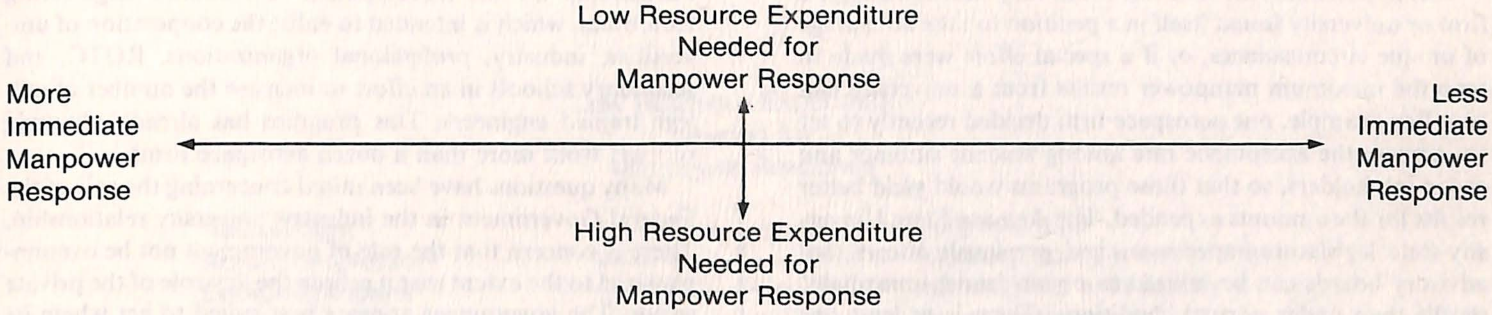
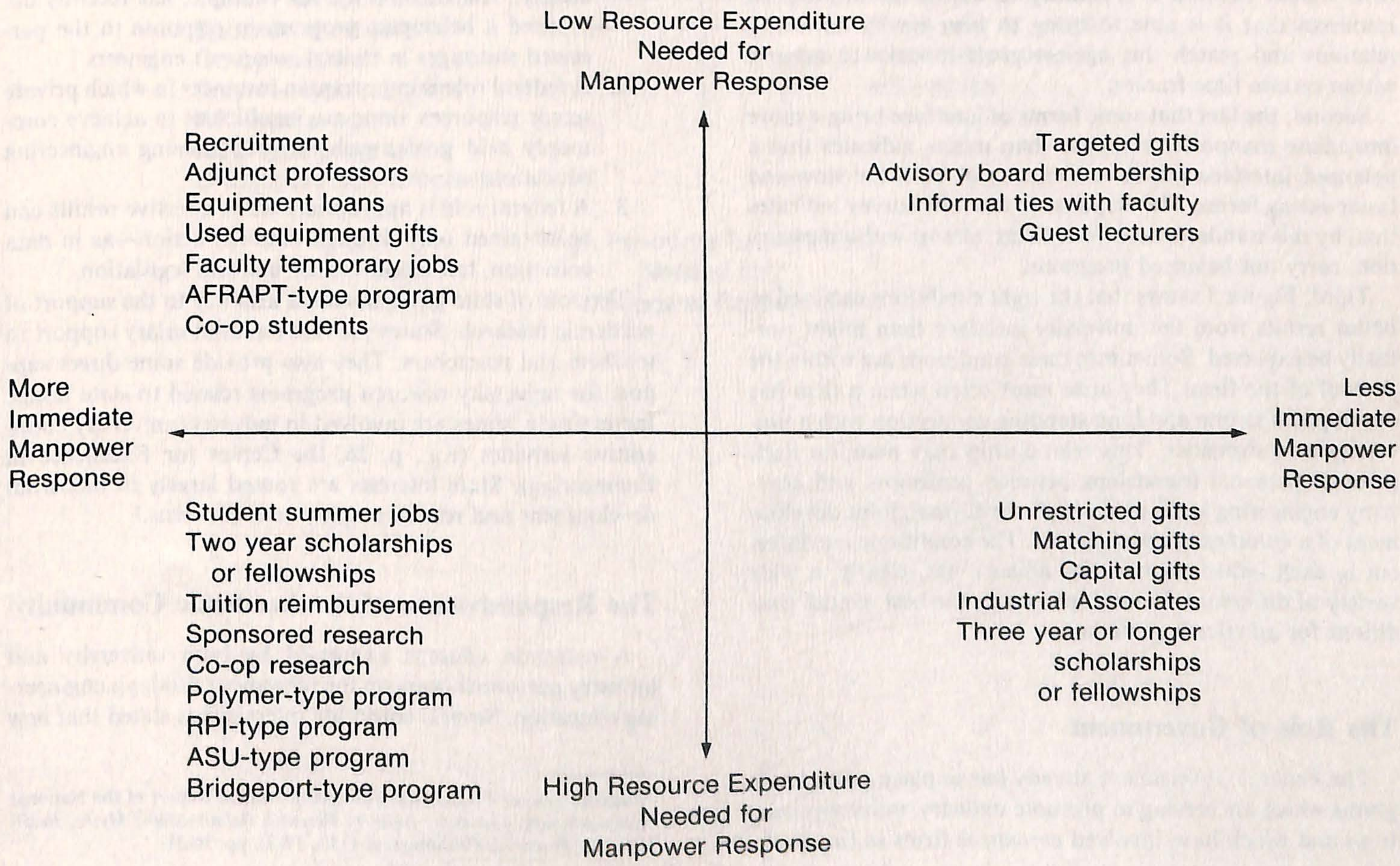


FIGURE 2

HYPOTHETICAL DISTRIBUTION OF FORMS OF INDUSTRY/UNIVERSITY INTERFACE, ACCORDING TO TIME/RESOURCE MATRIX



increased numbers of students and/or faculty, or better quality of same. The distinction between "more" and "less" immediate response is set at two years, to include co-op student programs in the former category and longer scholarship programs in the latter.

This hypothetical distribution could vary substantially, if a firm or university found itself in a position to take advantage of unique circumstances, or if a special effort were made to reap the maximum manpower results from a university liaison. For example, one aerospace firm decided recently to try to increase the acceptance rate among student summer and co-op job holders, so that those programs would yield better results for the amounts expended. The Arizona State University-state legislature experience cited previously shows that advisory boards can be utilized to obtain "more immediate" results than under normal conditions. There is at least one case in which a prestigious four-year, undergraduate scholarship program has paid manpower dividends by making the cooperating firm the preferred employer for many other students in the area.

Figure 3 illustrates what the time/resource matrix might look like under hypothetical, optimum conditions, as reflected in these isolated cases.

Several lessons and conclusions can be drawn from this exercise. First, the matrix provides a basis for a corporation to construct a coherent policy toward its interface with universities. The time/resource constraint concept suggests that a firm should develop a capability to assess the amount of resources that it is able to bring to bear on its university relations and match this against goals it seeks to achieve within certain time frames.

Second, the fact that some forms of interface bring a more immediate manpower response than others indicates that a balanced interface will have elements of both the slow-and faster-acting forms. The response to the AIA survey indicates that, by this standard, aerospace firms, almost without exception, carry out balanced programs.

Third, Figure 3 shows that the right conditions can lead to better results from the university interface than might normally be expected. Sometimes these conditions are within the control of the firm. They arise most often when a firm has developed a strong and long-standing connection with a university or universities. This relationship may manifest itself through personal friendships between professors and company engineering staff, or through the formal, joint development of a complex research center. The conditions are different in each industry/university alliance but, clearly, a wide variety of different relationships creates the best overall conditions for an effective interface.

The Role of Government

The Federal Government already has in place several programs which are serving to promote industry/university relations and which have involved aerospace firms in the implementation. The Polymer Processing Program, for example, was started with seed funds from the National Science Foundation. The Air Force has programs similar to AFRAPT in the fields of composites (where several aerospace firms are involved) microwaves, vacuum tubes, and manufacturing technology. The Department of Defense has announced a Partnership for the Development of National Engineering Resources, which is intended to enlist the cooperation of universities, industry, professional organizations, ROTC, and secondary schools in an effort to increase the number of college trained engineers. This program has already obtained support from more than a dozen aerospace firms.

Many questions have been raised concerning the role of the Federal Government in the industry/university relationship. There is concern that the role of government not be overemphasized to the extent that it eclipse the key role of the private sector. The government appears best suited to act where its prestige, programs and financial support can have a catalytic effect on the industry/university relationship, and where private resources are insufficient for a task in which the government has a vital interest. Based upon the successful industry cooperation encountered in the programs just described, it seems possible to state some general principles concerning the role of government in initiating and maintaining industry/university relations.

1. A federal role involving direct outlays and subsidies may be necessary when specific national interests are at stake and when federal participation can be defined clearly. The U.S. Army, for example, has recently developed a helicopter program in response to the perceived shortages in trained rotorcraft engineers.
2. A federal role is important in instances in which private sector resources alone are insufficient to achieve commonly held goals, such as strengthening engineering education.
3. A federal role is appropriate when effective results can be obtained only through national action—as in data collection, tax incentives, or uniform legislation.

The role of state governments is also key to the support of academic research. States provide essential salary support to teachers and reseachers. They also provide some direct support for university research programs related to state needs. Increasingly, states are involved in industry/university cooperative activities (e.g., p. 26, the Center for Excellence in Engineering). State interests are rooted largely in industrial development and related employment concerns.[3]

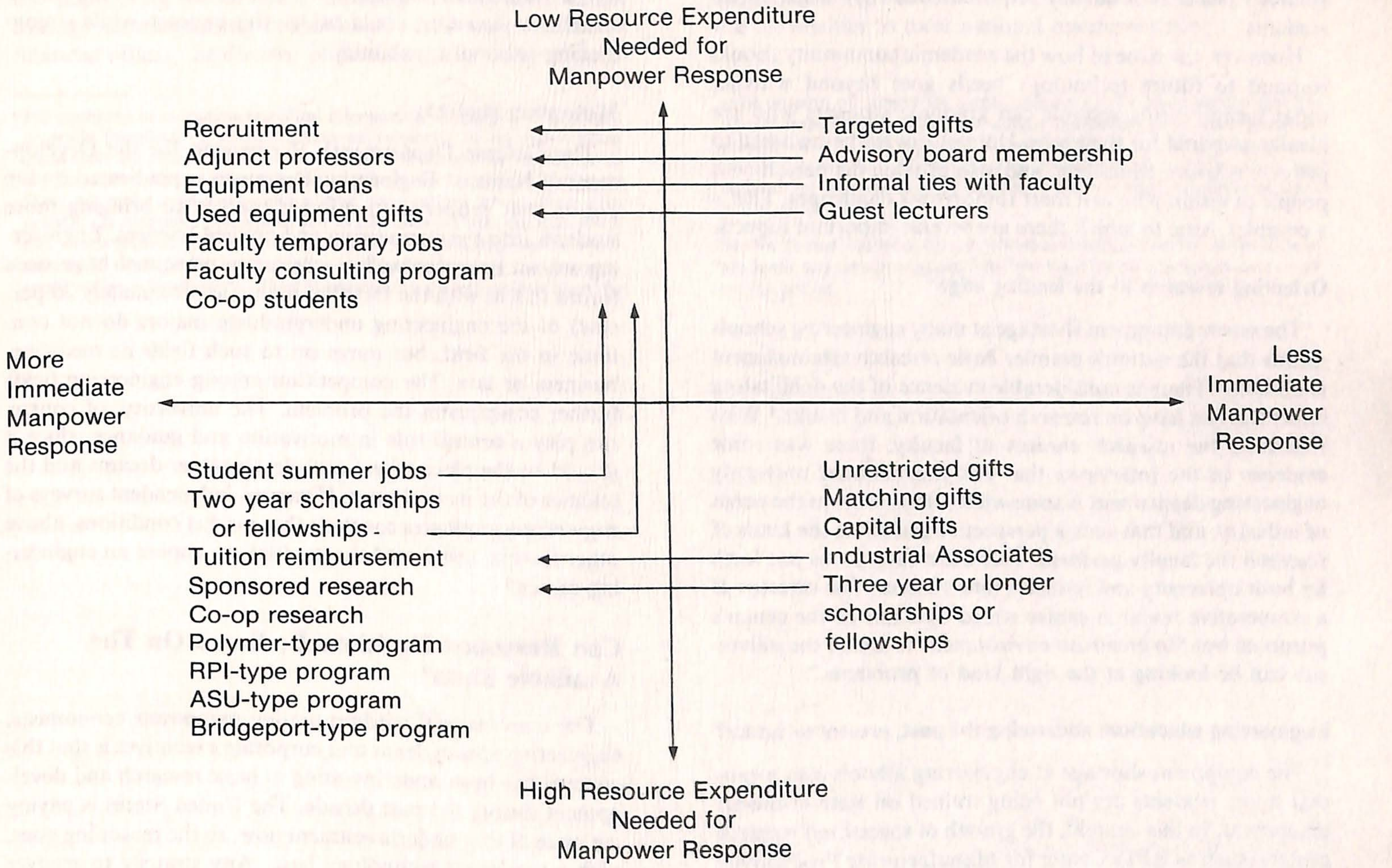
The Responsiveness of the Academic Community

A common concern expressed by both university and industry personnel bears on the relevance of today's engineering education. Several corporate interviewees stated that new

[3]National Science Foundation Fourteenth Annual Report of the National Science Board, *University-Industry Research Relationships: Myths, Realities and Potentials* (Washington, D.C., 1983), pp. 30-31.

FIGURE 3

REDISTRIBUTION OF FORMS OF INDUSTRY/UNIVERSITY INTERFACE ACCORDING TO OPTIMUM TIME/RESOURCE MATRIX



university graduates in some fields, such as manufacturing engineering, enter the firm with so few relevant skills that they must devote two years or more to learning the basics of their profession. Nevertheless, in dealing with industry, universities appeared to hold tenaciously to the view that they alone were competent to determine what was of educational value to their student body. This colored the kinds of sponsored research they were willing to undertake and the kinds of restrictions (such as residency requirements) they imposed on students.

However, the issue of how the academic community should respond to future technology needs goes beyond whether today's engineering schools can graduate students who are ideally prepared for their jobs. Universities are being asked to provide relevant education, and also provide the nation with people of vision who can meet tomorrow's challenges. This is a complex issue to which there are several important aspects:

Orienting research to the leading edge

The severe equipment shortage at many engineering schools means that the nation's premier basic research establishment is obsolete. There is considerable evidence of the debilitating effect this can have on research orientation and results.[4] With regard to the research choices of faculty, there was some evidence in the interviews that the conventional university engineering department is somewhat removed from the needs of industry, and that such a perspective can affect the kinds of research the faculty perform. This observation was put forth by both university and industry interviewees. The director of a cooperative research center stated that one of the center's purposes was "to create an environment in which the university can be looking at the right kind of problems."

Engineering education: addressing the past, present or future?

The equipment shortage at engineering schools also means that many students are not being trained on state-of-the-art equipment. In this context, the growth of specialized research centers (such as RPI's Center for Manufacturing Productivity and Technology Transfer) represents an effort to be more sponsor-oriented and, thereby, able to attract funding for up-to-date teaching facilities. At least one engineering department head decries this practice. "In the next 10 years," he said, "developments such as Cad/Cam will be obsolete as we know them today. Our engineering schools need to train the leaders who can make the right decisions for the next generation of invention." Thus, universities appear to be caught in a web of constraints, competing needs, and divergent views over the directions that engineering education should take.

Anticipating future technology trends/opportunities

The realities of international competition have raised the specter of a United States becoming outclassed, technologically, by countries whose business leaders have a sharper vision of future technology trends and opportunities. But, even in this urgent situation, there is some question of just how far the industrial sector-university partnership could or should extend in order to ensure the continued preeminence of American technology. A national policy of heavily promoting industry/university cooperation to produce commercially exploitable technology would change the shape and complexion of American universities. A new tier of collaborative structures, however, could bridge this concern while strengthening national capabilities.

Motivating students

The Defense Department's Partnership for the Development of National Engineering Resources is predicated on the notion that proper motivation is the key to bringing more students into the engineering and applied sciences. Engineering school deans as well as corporate personnel have been forced to live with the fact that many (approximately 20 percent) of the engineering undergraduate majors do not continue in the field, but move on to such fields as medicine, business or law. The competition among engineering fields further complicates the problem. The university, of course, can play a central role in motivation and guidance, since it should be the place where a student's career dreams and the realities of the market meet. However, independent surveys of engineering graduates conclude that market conditions, above other factors, influenced the graduate to choose an engineering career.[5]

Can Reasoned Decisions Be Based On The Available Facts?

The conventional wisdom among manpower economists, engineering school deans and corporate executives is that this country has been underinvesting in basic research and development during the past decade. The United States is paying the price of that underinvestment now, so the reasoning goes, with a weakened technology base. Any strategy to recover lost ground, including efforts to rebuild the country's defense capability, runs up against the fact that there are not enough advanced degree engineers in certain fields; nor are there enough university faculty members to train the needed numbers of new engineers.

Beyond this commonly held view, which is accepted as fact, the evidence becomes rather hazy. "Authoritative" estimates of the manpower supply and demand abound, but each contains flaws that could alter an assessment of the situation

[4]Bruce L. R. Smith and Joseph J. Karlesky, *The Universities in the Nation's Research Effort* (New York: Change Magazine Press, 1978). p. 156.

[5]William R. Upthegrove, *"Engineering Manpower Issues: Must It Always Be Feast or Famine?* Business-Higher Education Forum (American Council on Education (1980), pp. 12-13. See also, David Breneman, "Graduate Education in Science and Engineering: Prospects and Policy Options" unpublished manuscript, Washington, 1980, p. 3.

substantially.[6] Much of the reliable information is anecdotal, which means that aggregate statistics are not generally available.[7] Information about laboratory equipment is especially difficult to come by.

In order to ascertain the true extent of the interface with industry at the average university, interviews might be required with the development officer, the director of the office of sponsored research, the industrial liaison officer, the dean of the engineering school and a sampling of professors. At the average manufacturing corporation, visits with the senior financial officer, the director of personnel, the research director, the person in charge of contributions, and the university liaison officer would be necessary in order to grasp the firm's interface with universities. Even then, if a firm had several subsidiaries, this process might have to be repeated at each one.

Both industry and academia need fact-finding apparatuses capable of functioning effectively and of exchanging information. It is crucial that a means be devised to take full stock of the engineering manpower situation, as well as the ability of the universities to meet national manpower needs.

[6]The problems of compiling statistical information on manpower needs are generally threefold: (1) questionnaires on corporate hiring plans, which could establish an empirical basis for calculating manpower needs, tend to overstate the amounts of manpower required, since individual firms are likely to make collectively inconsistent assumptions about their own growth; (2) economic projections fail to take into account the manpower mix which is involved in different phases of the engineering-intensive product cycle (outlays for new weapons system development, for example, could utilize a significantly different engineering manpower mix than the same amount of outlays for manufacturing a fully developed system); (3) several important variables are almost impossible to predict, given the present state of the economists' art, including the likely numbers of transfers in and out of particular engineering fields (such transfers can account for differences of 20 percent of more in one's estimates of manpower needs).

[7]See Smith and Karlesky, *op. cit.*, whose authoritative survey on the state of academic science was supported by "site visits" to 36 universities over an 18 month period.

LEGISLATION

Legislation germane to the issue of industry/university interface includes the authorizing acts for the National Science Foundation (NSF) and the Office of Science and Technology Policy (OSTP), the Stevenson-Wydler Technology Innovation Act of 1981, the Economic Recovery Act of 1981, which includes R&D incentives, and various other bills currently under consideration in Congress including various appropriations requests in support of science and engineering research.

The National Science Foundation Act of 1950 authorized the NSF, which it created, "to initiate and support basic scientific research and programs to strengthen scientific research potential and scientific education programs at all levels in the engineering ... sciences...; to award ... scholarships and graduate fellowships in the ... engineering ... sciences ...; ... to foster and support the development and use of computer and other scientific methods and technologies ...; (and) ... to maintain a current register of scientific and technical personnel ... (for analyzing) the current and projected need for, scientific and technical resources in the United States..."[1] The act also directs the NSF to recommend national policies to strengthen basic research and science education. To carry out the functions of the National Science Foundation during Fiscal Year 1983, the Reagan administration requested $1,072.8 million. This compared with actual spending in FY 1981 of $1,041.8 million, and estimated FY 1982 outlays of $996.3 million. Appropriations levels for basic research and graduate education in relevant engineering sciences kept pace with inflation, in the case of computer research, but declined in either real or constant dollar terms in other areas including: science and engineering faculty improvement programs, graduate research fellowships in science and engineering, and science resource studies (including manpower surveys).[2] There had been a relatively large increase in funding for science resource studies in FY 1982, however, which was ascribed largely to NSF's post-census survey of scientific and engineering manpower.

In early February 1983, President Reagan sent to Congress a budget for Fiscal Year 1984 which provided a significant increase of funds for basic research in the physical sciences, mathematics and engineering. Where the Administration had earlier attempted to eliminate NSF's educational programs, it is now proposing modest increases. In fact, the largest increase in R&D funding among civilian agencies has been earmarked for NSF. Under Reagan's plan, the agency's budget would rise 18 percent to $1.29 billion. Increases above 18 percent are being requested for basic research in mathematical and physical sciences and astronomical, atmospheric, earth and ocean sciences. Engineering funding is to increase 22 percent over FY 1983, bringing funding over the past two years from $83 million to $123 million. Expenditures on R&D equipment and instrumentation are to increase from $112.3 million in 1983 to $180.2 million in 1984, an increase of more than 60 percent.

A major new endeavor under the Reagan budget is to fund scholarships through the Department of Education to produce 7,000 math and science teachers a year. Graduate fellowship funding will also increase from $6,900 to $8,100 and include support for Presidential Young Investigators Research Awards—grants of up to $50,000 for as much as five years; matching funds will be required for this federal program. Support of precollege education, eliminated by the Administration when it took office, will be reinstated. It will focus on awards for teaching excellence with grants to winners' schools and a major initiative to retrain teachers to improve science and math education in secondary schools. Federal funds—$19 million—would be provided on a matching basis.

The National Science and Technology Policy, Organization and Priorities Act of 1976 established an Office of Science and Technology Policy within the Executive Office of the President, and gave it certain coordination and policy development authority. The legislation was enacted in response to a perceived need by Congress to strengthen the country's capabilities for technology assessment and for technological planning and policy formation. The intent of the act has been to give science and technology policy a higher profile within the White House, and to introduce science and technology considerations more fully into federal policymaking. Budget outlays for the Office of Science and Technology Policy have been, or will be, $1.6, $1.6, $1.9 and $2.1 million, respectively, for fiscal years 1981, 1982, 1983 and 1984. In fiscal year 1982, the permanent civil service staff (GS-15 and below) was cut in half. Overall staffing, which includes the director and several senior executive service personnel, remained relatively constant at 12 for FY 1981, and 11 for FY 1982 and 1983. It is slated to increase to 15 under the FY 1984 budget.[3]

[1] P.L. 81-507, S3, 64 Stat. 149, as amended (42 U.S.C. 1862).

[2] National Science Foundation, *FY 1983 Budget in Brief to the Congress*, pp. 35, 37, 42-43.

[3] *The Budget of the United States Government, Fiscal Year 1983, Appendix op. cit.*, pp. I-C8, II-11.

The Stevenson Wydler Technology Innovation Act of 1980[4] was intended to fill a gap in federal policy by drawing together some existing and new provisions, into a comprehensive package for promoting technological innovation.

The act directed the Secretary of Commerce to establish an Office of Industrial Technology, which would perform a variety of policy research and coordination functions within the department. The Administration has since set up an Office of Productivity, Technology and Innovation to carry out the duties set forth in the act, plus other responsibilities.

The Administration has proposed a FY 1984 budget of approximately $5.7 million under the Assistant Secretary of Productivity, Technology and Innovation. The program of the new Commerce office has been strongly focused around an Industrial Technology Partnerships Program. The program is based on a concept of research and development limited partnerships to develop new products or proprietary processes. These partnerships may involve private companies, independent entrepreneurs, universities, or government organizations such as federal laboratories. The Industrial Technology Partnerships Program is seen, in conjunction with investment incentives provided by the Economic Recovery Tax Act of 1981, as an important stimulus to productivity, technology and innovation. The program itself is to be funded for approximately $1 million under the Administration FY 1984 budget. Other programs and activities within the Commerce office, however, are supportive of and tie into the industrial technology partnerships concept—patent licensing and policy, for example. With the current emphasis on this program, centers for industrial technology mandated under Stevenson-Wydler have not been established.

Section 8 of the Stevenson-Wydler Act wrote into law the program under which the National Science Foundation has funded projects such as the MIT Polymer Processing Program.

[4] P.L. 96-480, October 21, 1980, 94 Stat. 2311 (15 U.S.C. 3701).

Section 11 of Stevenson-Wydler directed establishment of a Center for the Utilization of Federal Technology in order to facilitate transfer of federally-owned information to state and local governments, and to private industry. The center was not funded in FY 1983 but the Administration has requested $0.5 million for FY 1984.

Section 13 directed the National Science Foundation and the Secretary of Commerce to establish a program to foster the exchange of scientific and technical personnel among academia, industry and federal laboratories. The intent was that some of these exchanges would be federally funded but that efforts also would be made to facilitate these exchanges without federal funding. Some Commerce and National Science Foundation staff time has been devoted to this concept; the program, however, has not been funded.

Stevenson-Wydler also mandated a National Industrial Technology Board of outside experts and leaders in technology, labor and industrial innovation. The intent was to expand the Department of Commerce's existing Technical Advisory Board at the Department of Commerce, which has fallen into relative disuse. The board has not been established, although consideration has been given to a presidential advisory board along these lines.

Appropriations for Research and Development at the Department of Defense and at the National Aeronautics and Space Administration are two important sources of R&D funds affecting the aerospace industry. The following table sets forth these funding levels and the requested appropriations for FY 1984.

The Department of Defense R&D budget mirrors the priority given by the Reagan Administration to national security projects. The National Aeronautics and Space Administration budget is in line with the lesser emphasis given at this time to civilian space efforts. Nonetheless, after downplaying the role of aeronautical funding within NASA

TABLE 2

CONDUCT OF R&D BY THE DEPARTMENT OF DEFENSE AND BY THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Department/Agency	Outlays (in millions)			
	FY 1981 (actual)	FY 1982 (actual)	FY 1983 (est.)	FY 1984 (est.)
Department of Defense	$15,720	$18,201	$21,847	$26,844
National Aeronautics and Space Administration	$5,279	$3,220	$2,386	$2,421
	Obligations (in millions)			
NASA Aeronautical R&D	$271	$258	$313	$300

Source: *The Budget of the United States Government, Special Analysis K, Research and Development,* 1982, p. 5.

PENDING LEGISLATION - 98th CONGRESS PERTAINING TO SCIENTIFIC AND TECHNICAL MANPOWER

H.R. 481	Brown	National Technology Foundation Act of 1983
H.R. 582	Fuqua	To provide a national policy for engineering, technical and scientific personnel, to provide for cost sharing by private sector in training such personnel
H.R. 1310	Perkins	Emergency Mathematics and Science Education Act
H.R. 1411	St. Germain	To amend the Defense Production Act to establish a grant program to assist institutions of higher education to obtain/install modern equipment needed to train professional/scientific and technical personnel
S. 631	Tsongas	High Technology Morrill Act—public/private funding of technology education proposals
S. 949	Chiles	To povide a program to increase the literacy of the American public in the fields of mathematics, science and technology
S. 614	Gorton	To establish within the Office of Science and Technology a Presidential Program for the Advancement of Science and Technology

for several years, the new Reagan Administration budget calls for $300 million, a $20 million increase over FY 1983. (The Administration's original request had been $230 million in FY 1983; Congress increased it to $280 million.) The increased aeronautics funding is rooted in the Administration's new civil aeronautics policy as enunciated by Presidential Science Advisor George Keyworth following an intensive study of the issue by the Office of Science and Technology Policy. The Administration has recognized the importance and appropriateness of federal support in this area.

Section 221 of the ***Economic Recovery Tax Act*** (ERTA) (P.L. 97-34) allows a 25 percent tax credit for a firms' incremental R&D expenditures. However, only 65 percent of contracted research or basic research grants to universities may count in the calculation of the credit. U.S. Treasury estimates of the revenue effects of this provision are consistent with a 5.3 percent rise in R&D outlays for those firms who increase their R&D.[5] This amounts to a decrease in R&D in real terms.

It is arguable that aerospace firms are in a better position to take advantage of this provision than other industrial sectors, considering the increase in defense spending. Responses to the questionnaire developed for this report indicate, however, that most firms will not significantly expand their involvement with universities as a result of the incentives in ERTA. A reason commonly cited for this was that any advantage gained from tax incentives would go to meeting other company needs, such as capital investment or in-house research.

A legislative proposal introduced by Congressman Fuqua in 1982 and reintroduced in 1983, the National Engineering and Science Manpower Act of 1983 (H.R. 582), attempts to address how the United States can ensure an adequate supply of technical, engineering and scientific personnel. The bill would establish a Coordinating Council on Engineering and Scientific Manpower within the National Science Foundation, with representatives from academia, industry and the leading science policy advisers in the Federal Government. The council would incorporate, or assist in, some of the monitoring and assessments of manpower supply currently being carried out by the National Science Foundation and the Office of Science and Technology Policy. It would have additional functions of, for example, making policy recommendations specific to the issue of science/engineering manpower goals.

The bill would establish an Engineering and Science Manpower Fund within NSF to provide grants—on a matching basis with funds from other public sector sources and the private sector—for fellowships, laboratories and lab equipment, salaries, and research. H.R. 582 also addresses the

[5]The Office of Tax Analysis, U.S. Treasury Department has estimated a $448 million revenue loss from section 221. Since the provision does not affect firms which decrease their R&D outlays, the $448 million refers to 25 percent of the incremental R&D oulays of those firms which actually spent more, or $1,792 million. The National Science Foundation estimates that industrial R&D outlays in 1981 stood at $33,865 million. See *Science Indicators 1980, op. cit.*, p. 248.

issues of high-technology technician training and the improvement of math and science instruction, and would authorize appropriations for the modernization of instructional equipment.

Another bill dealing with technological manpower supply and demand has been introduced by Congressman George Brown, Jr. of California. H.R. 481 establishes a National Technology Foundation consolidating in a single agency programs in the Department of Commerce and The National Science Foundation designed to facilitate the advance of technology, technology innovation and utilization, and the supply of technological manpower. The bill attempts to incorporate features of the Stevenson-Wydler Technology Innovation Act by putting the Office of Industrial Technology functions into the technology and policy analysis branch of the new foundation and responsibility for support of centers for industrial technology into an institutional and manpower development branch. The new foundation and the National Science Foundation would have interlocking directorates.

Senator Paul Tsongas of Massachusetts has introduced S. 631, calling for public-private joint funding of technology education proposals initiated by a corporation and university, approved by state government, and granted by Federal Government. The purpose is to promote economic development in the states emphasizing innovative, productive projects which can serve as models for emulation.

Other pertinent legislation is included in the box on page 36.

It would appear that in both the Administration and in Congress there is a growing awareness of the important role of science and engineering, and science and engineering manpower, in the U.S. economy—and that this awareness is beginning to be translated into action.

AIA INDUSTRY/UNIVERSITY RELATIONS SURVEY

While much of the report included in these pages was based on interviews conducted by a consultant with AIA member company representatives as well as university, government and private sector spokesmen, a vital element of the study was a survey developed and administered by AIA Research Center staff. The survey questionnaire, reviewed by an ad hoc advisory group of the Aerospace Technical Council, was designed to obtain the best possible sounding of AIA member ties to the university community.

Through the survey, companies were asked to report the amount of funding going to universities, and to give some indication of the trend in funding categories. In addition, the survey sought subjective responses concerning incentives and disincentives to industry involvement with higher education, suggested solutions to problems that have arisen, and current engineering manpower concerns. Companies were asked to look into the future and describe expected changes in the mix of engineering manpower over the next five to 10 years. Finally, AIA members were asked how the Federal Government might best facilitate industry/university relations, and the role they would like the aerospace industry and AIA to play in promoting development of engineering manpower through the university relationship.

Companies were asked to provide a single, coordinated response by July 9, 1982. Data was to represent company funding for the 1981 calendar year.

Survey Design

It was understood from the beginning that the nature of industry's ties to academe would make it difficult to collect and compare data. Relationships with the university community take many forms (more than 20 were described in the survey itself; numerous others were reported). They may be highly structured, well-documented relationships—or they may be more informal, based on long-standing personal ties between a company and university personnel, and documentation may be slim. At times, it is difficult to assign a value to the extent of industry involvement with education. This is particularly true where a great deal of interaction occurs between company staff and the university that cannot be quickly captured and labeled as "contribution" or "cost."

Another complicating factor in the collection of data is the complexity of relationships within a single company, wherein one division or office will have established university ties quite different from those of another. Data on these relationships are not necessarily kept in consistent fashion, either throughout a single company or among companies. A further difficulty for some would be to separate funding related to engineering and applied science interests from those in support of higher education as a whole.

Still another factor considered was the diversity of companies within AIA ranging from major manufacturers of aircraft, aircraft engines, and missiles to those producing related high-technology components, equipment and materials. While a number of companies could categorize their business as primarily aerospace, nearly every company has a diversity of business interests that make it an onerous task to differentiate funding for aerospace education from funding for other business activities. These considerations led to the practical decision to ask for total university funding on a corporate level, including funding for liberal arts and other non-engineering related disciplines.

When companies responded, most indicated their data represented company-wide funding, as requested. Seven provided responses for the aerospace segment of their company or for a segment that is primarily engineering-oriented. In one instance, only the aerospace-related division of a corporation is a member of the AIA, and only that division responded. It should be noted, too, that a number of companies indicated their funding estimates were conservative. Overall, the actual amount spent on university relationships would, no doubt, be higher than reported.

There was an excellent response to the survey with replies from 33 companies or 68 percent of AIA members.

Although the data gathered by the survey does not represent only the aerospace-related business of AIA member companies, with the exceptions noted, the data obtained should give a fair indication of the types of involvement, the relative levels of spending on different activities, and the trend toward involvement in various areas with the university community.

Survey Results

When tabulated, the AIA Industry/University Relations Survey showed that member companies provided more than $117.8 million in funding to promote ties with the university community in the calendar year 1981. Of this amount, $84 million (about 70 percent) was estimated to have been spent on the promotion of engineering and applied science.

Funding Categories

Program, faculty and student support is the major expenditure category at $36.9 million, with research second at $27.9 million; acquisition of university services received $20.9 million and gifts an amount of $20.6 million. Other funding not accounted for in any of the specified categories came to $11.5 million. In this miscellaneous category, companies mentioned a variety of projects such as surplus equipment gifts, support of instructional TV, contributions to educational foundations, associations and similar organizations. (Table 1 provides additional details and figures.)

Program, Faculty and Student Support. Quite a lengthy list of possible relationships—13 in all—was included under the survey category of program, faculty and student support. This category, as mentioned earlier, received the greatest portion of total funding, and of the items in this classification, undergraduate scholarships drew the largest amount—$7.7 million. Most of this (79 percent) went to engineering and applied science students.

Table 2 lists the 13 possible connections along with the number of schools involved, estimates of funding and an indication of the commitment trend.

TABLE I

MAJOR CATEGORIES OF AEROSPACE COMPANY EXPENDITURES[a] IN UNIVERSITIES 1981 (Millions of Dollars)

	Total Funding	In Support of Engineering and Applied Science Programs
Program, Faculty and Student Support	$ 36.9	$ 27.8
Research[b]	27.9	22.7
Acquisition of University Services	20.9	12.1
Gifts	20.6	13.1
Other	11.5	8.2
	$117.8	$ 83.8

[a] Funding totals represent expenditures of 33 member companies of the Aerospace Industries Association (for information on data collection see p. 88).

[b] Includes R&D contracts, cooperative research projects and industrial associates programs (see Table 2).

All funds for employment of faculty on sabbatical were linked to engineering and applied science; so, too, were funds for prototype development, fabrication and testing services, and nearly all funding involving university use of industry-owned facilities and equipment. More than 85 percent of funds for advisory council participation, industrial fellowships and graduate scholarships were also linked to engineering and technical programs, as were three quarters of faculty chair endowments.

Aerospace companies reported providing program, faculty and student support to numerous academic institutions during 1981—from one or two to as many as 200 in one category of activity (full or partial support of adjunct faculty salaries). The average number of schools receiving such faculty salary assistance was 33. One firm reported employing students from 150 schools (average was 41); another provided undergraduate scholarships to 128 (average was 32). Still another company was involved in student co-op programs with as many as 110 academic institutions (average was 13). The greater numbers may reflect the largest, most diversified organizations. However, several companies commented that many, if not all, of their scholarships were provided to sons and daughters of employees; a large number of school affiliations, therefore, is not surprising in that category.

Asked to report the number of years of their longest relationship with an academic institution, replies ranged from one to 60 years. In many categories, the top of the range exceeded 20 years. The averages, however, were much lower and ranged from two to 17.

Research. Survey respondents were queried about R&D contracts, cooperative research projects, and industrial associates programs. The total amount spent in these three types of relationships came to $27.9 million. Just over 60 percent of research funds and about 70 percent of industrial associates funding involved engineering and applied science. As would be expected, nearly all (98 percent) of R&D contracts were in engineering and applied science disciplines. The number of schools with which companies had research ties—other than contracts—ranged from one to 26 (seven was average). Some relationships had lasted for more than 30 years; the average was eight years for cooperative research projects and 15 for associates programs. Companies had R&D contracts with anywhere from two to 50 schools (12 was average). Some of these relationships had lasted 25 years, although eight was the average. (See Table 2 for additional details.)

Acquisition of University Services. In this category, 60 percent of the arrangements for the education and training of industry employees involved engineering and applied science while this was true of less than one third of industry's purchase of university facilities. Industry's relationship with academia for the purpose of employee training had the longest history (22 years on average) and involved the greatest number of schools per company (55 was average). (See Table 2.)

Gifts. Under the broad category of gifts, respondents were asked for information on directed contributions (for construction, renovation and equipment), matching gifts, and

TABLE 2

AEROSPACE COMPANY EXPENDITURES IN UNIVERSITIES[a] BY TYPE AND NUMBER OF RELATIONSHIP AND TREND OF COMMITMENT 1981 (Millions of Dollars)

	Type of Relationship	Number Schools (Range/Average)	Estimate of Funding	Trend of Commitment[b]
PROGRAM, FACULTY & STUDENT SUPPORT	Undergraduate scholarships	1-128/30	7.7	3.3
	Student co-op programs	1-110/19	5.4	3.3
	Hire faculty consultants	4-50/15	5.3	3.4
	Other full or part-time employment for students	1-150/40	4.7	3.3
	Endow faculty chairs	1-5/3	4.5	3.0
	Graduate scholarships	1-40/12	3.7	3.4
	Loan use of facilities, laboratories, computers	1-18/6	1.2	3.5
	Industrial fellowships	1-14/6	1.0	2.8
	Full or partial support of adjunct faculty salaries	1-200/29	1.1	3.3
	Employ faculty on sabbatical	1-7/2	1.0	3.3
	Summer employment for faculty	2-10/4	.6	3.2
	Prototype develop. fabrication, testing	1-5/3	.5	3.3
	Advisory council participation	1-25/7	.2	3.6
RESEARCH	R&D contracts	2-50/12	14.5	3.5
	Cooperative research projects	1-24/7	8.6	3.5
	Industrial associates programs	1-26/7	4.8	3.4

[a] Funding totals represent expenditures of 33 member companies of the Aerospace Industries Association (for information on data collection see p. 38).

[b] Scale: 1 - Strong decrease; 2 - Moderate decrease; 3 - Steady level; 4 - Moderate increase; 5 - Strong increase.

TABLE 2
(continued)

	Type of Relationship	Number Schools (Range/Average)	Estimate of Funding	Trend of Commitment[b]
GIFTS	Unrestricted gifts	1-75/22	8.3	3.4
	Directed contributions	1-60/14	7.3	2.9
	Matching gifts	1-18/1495/374	5.0	3.7
ACQUISITION OF UNIVERSITY SERVICES	Employee education and training	4-200/55	19.5	3.7
	Use of university facilities	1-6/3	1.4	3.5
OTHER		1-200/31	11.5	3.2

[a] Funding totals represent expenditures of 33 member companies of the Aerospace Industries Association (for information on data collection see p. 38).

[b] Scale: 1 - Strong decrease; 2 - Moderate decrease; 3 - Steady level; 4 - Moderate increase; 5 - Strong increase.

other unrestricted gifts. Sixty-seven percent of directed contributions were judged to have been spent in science while 38 percent of matching gifts went to those disciplines. Respondents were also asked for the number of schools with which they have current relationships in each category. Results showed a range of from one to 60 (14 was average) for directed contributions and from one to 75 (22 was average) for unrestricted gifts. A much wider range—from 18 to 1,495 (374 was average)—was reported for matching gifts. In reporting existence of the longest relationship with a school, answers ranged from one to 30 or 40 years (Table 2).

Other. As indicated earlier, quite a bit of industry involvement with U.S. schools did not fit into the categories outlined. As a result, AIA member companies reported $11.5 million in "other" funding and said that roughly 70 percent of these activities could be considered engineering/technology related (Table 2).

R&D Funds

The AIA survey asked companies to indicate as accurately as possible the percentage of *company-funded* research and development budgets going to universities in 1981; i.e., funds from a company's own R&D budget, rather than funds originating in government contracts. It should be noted that in a highly R&D-intensive industry, a large proportion of company-funded research will be spent on specific projects most easily performed and managed in-house. Not every survey respondent answered this question. In all, 21 companies replied. When averaged, these responses showed that 1.5 percent of company-funded R&D went to universities. The range of replied was from .01 percent to 5 percent. (See Table 3).

TABLE 3

PERCENT OF AEROSPACE COMPANY-FUNDED R&D BUDGETS EXPENDED IN UNIVERSITIES[a] 1981

Range	.01-5%
Average	1.5%

[a] Information represents response of 63 percent of survey participants, or 21 Aerospace Industries Association member companies.

AIA members were then asked to estimate how *total* R&D funds going to colleges and universities in 1981 were apportioned among four categories: company-funded, independent research and development, grants and sub-contracts. Table 4 carries the results of their tabulated replies.

TABLE 4

APPORTIONMENT OF TOTAL R&D FUNDS[a] EXPENDED BY AEROSPACE COMPANIES[b] IN UNIVERSITIES 1981

R&D Category	Percent Range of Respondent Replies	Percent Average of Respondent Replies
Company-funded	0-100%	34%
IR&D[c]	0-100	26
Grants	0-100	25
Sub-contracts	0-45.7	15

[a] Total R&D includes both company-funded and contracted funds, i.e., funds from all sources.

[b] Information represents response of 48 percent of survey participants, or 16 Aerospace Industries Association member companies.

[c] *Independent Research and Development* - a term devised by the Department of Defense (DOD) and used by Federal agencies to differentiate between a contractor's research and development technical effort performed under a contract, grant, or other arrangement (R&D) and that which is self-initiated and self-funded (IR&D).

Incentives to Industry Involvement

Respondents were asked to rank various possible incentives to involvement with universities, reflecting their own company's situation and experience. The order of the list which follows is based on the ranking of the replies:

- Recruitment of scientists and engineers;
- Development of qualified scientists and engineers;
- Development of new science-based technology to meet competitive challenges;
- Maintenance of vital R&D base for total national and industrial welfare;
- Stimulation of university interests in areas of industrial concern;
- Utilization of competent scientists around the country without expanding in-house capabilities, and,
- Development of new science-based technology to meet environmental, health and safety regulations.

Several other incentives were specified, including the need "to keep the universities in business and healthy in a time of financial difficulty," and "development of company-specific (and/or on-site) advanced degree education programs."

Asked if their companies had experienced any highly significant benefits from any of their university relationships, the larger proportion of respondents (63 percent) said "no," while 37 percent said "yes." In giving examples of major benefits or breakthroughs, most companies cited research advances. Some of the advances mentioned were in: integrated sensor technology; electro-optical guidance; electronic flight control; sophisticated software development; infra-red detection; and advanced air-foil design. Also cited were benefits from a cold weather transit research program and work in gas composition and turbulence flows. In addition, biomedical product testing and a research and plasma process for isotope separation were specified.

Elements of Success in Industry/University Relations

Respondents were asked to describe a successful company/university project and discuss the elements they felt made it a success. Responses focused on the importance of highly capable and motivated faculty members and graduate students and a commitment on the part of company researchers to follow work at the leading edge of technology—in other words, "high mutual technical enthusiasm." Patience with the university system was seen as a key element for industry and, over and over again, respondents stressed the importance of long-term relationships.

Economic Recovery Tax Act

Companies were asked what role the 1981 Economic Recovery Tax Act would play in their university relationships and did they foresee the act as significantly expanding university involvements? More than half (52 percent) said "no," 12 percent said "yes," and 36 percent said they "didn't know." (It should be noted that most responded before Congressional action to repeal many features of the act gained full steam in late summer of 1982, although the possibility of revisions had been widely discussed.) Respondents who said "no" indicated, first, that any advantage gained from tax incentives would go toward meeting other needs such as capital investment or in-house research; and, second, that they felt no immediate need for greater university contact.

Disincentives and Barriers to Industry/University Relations

Survey respondents were asked to rank a number of disincentives and barriers—14 in all—to industry/university relationships. All 14 had been cited as deterrents, to some extent, by both corporate and academic spokesmen. They are listed here in descending order of importance, as evaluated by the respondents;

- Concerns over patents and licensing rights to discoveries;
- University interests lie in freedom of communication and publication, while proprietary concerns are high with industry;

(The next two aspects were given almost equal weight.)

- University emphasis on education experience and extension of knowledge vs. commercial concerns of industry;

- Differing management philosophies (i.e., industry responsibility to stockholders for bottom-line results vs. university responsibility to public with respect to number and quality of students and research productivity;
- University has a longer time-frame for obtaining and reporting results than has industry;

(The next two were considered to be of equal importance.)
- Corporate dilemma over support of extramural vs. in-house research;
- Uncertainty of payback to industry;
- Attitudes of industry researchers/managers toward universities;
- Industrial need to respond in short-term to government regulations and changing economic conditions through incremental product changes, and process innovation;
- Multi-disciplinary nature of many industrial research projects;
- University emphasis on basic science and engineering, not development and commercialization;
- Attitudes of university researchers toward industry;
- Inability to adequately forecast industry manpower needs; and,
- University limitations on consulting.

Some other disincentives were advanced by survey respondents including, "competition for federal funding for research support," with the respondent indicating that "universities already benefit from a favored position for acquiring support for basic reseach."

Also seen as barriers to good relations were lack of accountability from universities, the high percentage of foreign national graduate Ph.D. students not readily employable by the aerospace industry, and security restrictions on certain activities. The high price of university-generated, company-specific advanced education programs was mentioned.

One respondent laid the difficulty at the door of "different cultures, and lack of easy ways to establish rich, warm (as opposed to formal), personal liaisons."

Eliminating Barriers

What kind of positive action would provide solutions to some of the primary difficulties in working with academia? A number of firms pointed out that the problem of the differing goals of university and industry is "fundamental" and "inherent" because of the varied roles of academia and business. Moreover, one said, the dichotomy is "hopefully permanent. Industry should encourage, and benefit from the university's primary function of education and training."

Most difficulties, it was suggested, "are soluble via a longer-term relationship, but these are difficult to set up with multiple universities, and technology needs change. Increased exposure of both faculty and students to industry's needs and constraints must be sought via all possible channels."

To address the concern considered primary by most respondents—that of patent and licensing rights—it was suggested by several that a consistent policy and standardized approach be developed to handle questions of patents and publication of information.

Respondents called for the universities to gear their programs to the practical needs of industry as well as toward academic/social goals. One company proposed, "More emphasis on fundamental engineering, related to existing hardware design . . . many products are evolutionary in nature and do not utilize leading edge technology." What might facilitate this process? One firm suggested federal funds be made available to industry for basic research, permitting industry to subcontract more research to universities in relevant areas. Another proposed more government grants to universities for projects that have industry timetables.

Finally, one respondent ventured this view: "The nature of the aerospace business causes companies like ours to generally be working in applied technology rather than basic research. In the few areas where we do research, our level of effort is on a par with or ahead of university effort. It is, therefore, difficult to work up areas of direct involvement. Nevertheless, we are working on ways to increase involvement and some are working—the key is to encourage communication, the rest should work out."

Engineering Manpower

Along with research interests, engineering manpower concerns are at the heart of the industry/university relationship for most firms, including those in aerospace. The AIA survey questioned members about their current major concerns relating to engineering manpower, and asked them to rank seven areas. They are listed here in descending order, as evaluated:

- Availability of specialized engineers;
- Quality of B.S. degree engineers;
- Shortage of Ph.D.s and advanced level qualified faculty to prepare tomorrow's engineers;
- Quantity of B.S. degree engineers

(The next two concerns were given equal weight.)
- Quantity of advanced degree engineers;
- Quality of advanced degree engineers; and
- Foreign degree candidates crowding out U.S. candidates, with ultimate implication of technology transfer.

Several companies pointed out that the problem with foreign students is, as one expressed it, "not one of their numbers but of the decreasing number of advanced degree candidates who are Americans." Most graduate engineering schools, it was suggested, need foreign students to maintain viable departments. Some companies find restrictive visa regulations as barriers to retaining foreign students educated in the United States.

Other concerns listed were salary levels of engineering professors, ill-equipped engineering laboratories, worn out equipment and engineering obsolescence.

Currently, most respondents have engineering recruitment problems in one or more areas. Twenty-two of the 34 responding firms cited difficulties in the broad areas of electrical and electronic engineering and computer science-based training. It was clear, however, that their concerns were with specialized types of engineers within these broad categories. Frequently mentioned were the need for engineers with backgrounds in: micro-electronics, electro-optics, computers/software, Cad/Cam, composites, stress and structures, polymer and non-polymer materials, and manufacturing process.

Asked to look ahead to possible changes in the mix of engineers in the next five to 10 years, survey respondents judged that the disciplines requiring the greater proportions of engineers would most likely be the again-mentioned computer science-based and electrical/electronic engineering fields. Overall, they did not expect to see the need for engineers in other categories increase or decrease significantly.

Government's Role

What kinds of government policies would constitute significant incentives to industry/university relations, or what kinds of roles should the government play in facilitating cooperation between academe and industry? When survey respondents were asked to react to a number of possibilities, the greatest number—91 percent—felt the government should afford R&D expenses a more favorable treatment. The other policies, or roles, are listed here along with a percentage figure which indicates the ranking in importance to the firms responding:

- 76% Lead in improving educational attainment in science and mathematics of all Americans;
- 64% Reduce federal disincentives in the area of patents, regulations, antitrust;
- 58% Remove antitrust restrictions that prove impediments to cooperative funding of generic research;
- 58% Strengthen National Science Foundation and other federal budgets for engineering education;
- 42% Improve long-term forecasting of manpower and technology trends;
- 33% Act as facilitator—identifying research problems and potential partners, and facilitating negotiations—between industry and universities;
- 30% Establish a national policy for engineering, technical and scientific manpower, coordinating national efforts through a federal-level council;
- 24% Establish an engineering and scientific manpower fund with matching federal-industry money;
- 24% Provide budget authority for the establishment of training and education programs in engineering, technical and scientific disciplines; and
- 15% Increase involvement, as a "third partner," in university/industry cooperative research programs.

A Role for Industry—and the AIA?

The aerospace industry obviously has a significant investment in the industry community and vital long-term interests in developing engineering manpower and the nation's research capabilities. What did members feel they might do to promote the development of engineering manpower? What might the Aerospace Industries Association do?

Looking first at the role of industry, the largest proportion (84 percent) of those responding felt the industry should interface more effectively with universities regarding its needs in the areas of engineering curriculum and technology trends. Seventy-two percent cited the need to establish communications programs that would encourage students to go into engineering and into aerospace. The earlier, more forceful communication of manpower needs to universities was important to 44 percent of the respondents; only about 20 percent felt the answer lay in pooling funds to support engineering scholarships and fellowships.

Where the role of the Aerospace Industries Association was concerned, most thought AIA should establish a program encouraging students to enter engineering and aerospace. About 70 percent felt the association could more effectively interface with universities concerning industry's needs. Communication of manpower needs and pooling of funds to support scholarships were seen as AIA roles by 41 and 16 percent, respectively.

Some other actions suggested were the funding of chairs in key technologies and enhancing engineering faculty salaries, in order to counter the present trend of industry hiring key faculty.

AIA

aerospace research center

1725 DE SALES STREET, N.W., WASHINGTON, D.C. 20036