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ABSTRACT

In the fall of 1986, a joint study was undertaken to solicit views of the nation's Governors, senior officers of U.S. companies, and presidents and deans of U.S. colleges and universities on the relationship of U.S. competitiveness to the human resource base and research and development capacity. Researches polled 1,300 senior research and development officers and 500 university leaders and senior state officials. Approximately 500 replies were received This report summarizes the survey findings and the discussion which occurred at the April 1987 regional meetings based on the survey's preliminary results. Specifically, the study was designed to address such issues as: (1) the importance of research and education to the economic competitiveness of the United States; (2) which of the following factors were believed to have the greatest impact on U.S. competitiveness--human resources, research and development investments, technology transfer, or federal fiscal, monetary, regulatory and trade policy; (3) what changes need to be made to strengthen and improve the nation's research and education system; and (4) the perceptions of three different communities--the business sector, the academic community, and state governments--with regard to research and education policies and the roles of each of these organizations to meet the competitive challenge of today's economy. Survey data and the discussions which occurred at regional meetings showed that there was a great deal of similarity in the perceptions of the three groups compared. The industry, university, and government leaders participating in the study agreed that science and engineering research and education have in the past, and will continue in the future, to play a crucial role in determining U.S. competitiveness. With regard to the most important factor affecting the nation's future competitiveness, all three groups viewed education as the key. Furthermore, there was general agreement that the area of education of greatest concern is mathematics and science education at the K-12 level. The survey instrument, a list of regional meeting speakers and panelists, and the National Governors' Association Issues Paper are included in three appendixes. (TW)

FINAL REPORT

The Role of Science and Technology in Economic Competitiveness

prepared by

National Governors' Association
Center for Policy Research

The Conference Board

with support and participation of the
National Science Foundation

THE ROLE OF SCIENCE AND TECHNOLOGY IN ECONOMIC COMPETITIVENESS

Final Report

Prepared For

The National Science Foundation

Prepared by

National Governors' Association
Center for Policy Research and Analysis

and

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The Study

In the fall of 1986, the National Governor's Association and the Conference Board, with support from the National Science Foundation, undertook a joint study designed to solicit the views of key industry, university and state government officials with regard to U.S. science and technology policies at both the state and federal level, and their relationship to the nation's competitiveness. During the winter and spring of 1987, researchers polled 2,300 senior research and development officers of technology-based companies, 500 university leaders and senior state officials responsible for science and technology policy in each of the fifty states. Approximately 500 replies were received.

The survey solicited the opinion of these senior officials on the impact of the following six areas on competitiveness: education and human resources, research and development resources, technology transfer, federal trade policy, federal monetary and fiscal policy, and federal regulatory policies. The survey also requested an assessment of existing state research and technology programs (APPENDIX I).

The preliminary survey results were used as the basis for three regional meetings held in April, 1987 in Seattle, Washington; Holmdel, New Jersey; and Dearborn, Michigan. University, industry, and state government officials were invited to discuss the survey findings and to discuss three key topics--meeting human resource needs, meeting research and development needs, and promoting commercialization (APPENDIX II).

This report summarizes both the survey findings and the discussion which occurred at the regional meetings. Survey findings and observations aggregated both nationally and by region (Pacific Coast-Rocky Mountain, New England-Middle Atlantic, Southern-Southeast, Midwest) are available upon request.

Center for Policy Research and Analysis

The National Governors' Association, founded in 1908, represents the Governors of the fifty states and the Commonwealth of Puerto Rico and the Northern Mariana Islands, the territories of the Virgin Islands, Guam and American Samoa. Its missions are to influence the development and implementation of national policy and to apply creative leadership to state problems.

NGA membership is organized into seven standing committees in major substantive areas: Agriculture, Criminal Justice and Public Protection, Economic Development and Technological Innovation, Energy and Environment, Human Resources, International Trade and Foreign Relations, and Transportation, Commerce and Communications. Special committees and task forces are formed in response to principal concerns of the Governors.

The Center for Policy Research and Analysis of the National Governors' Association serves as a vehicle for sharing knowledge of innovative programs among the states and provides technical assistance to Governors. The Center manages a variety of federal grants and foundation-funded activities and state demonstration programs in areas that include education, economic development, labor market and occupational analysis, socio-economic forecasting, health care financing alternatives, job training, and state human resource management systems.

The Conference Board

The Conference Board is a non-profit business research service whose purpose is to assist senior executives and other leaders in arriving at sound decisions. Since its founding in 1916, the Board has been creating close personal networks of leaders who exchange experience and judgment on significant issues in management practice, economics, and public policy. The networks are supported by an international program of research and meetings, which The Conference Board staff of more than 350 persons carries out from offices in New York, Washington, Ottawa, and Brussels.

More than 3,600 organizations in over fifty nations participate in The Conference Board's work as Associates. The Board is a not-for-profit corporation and the greatest share of its financial support comes from business concerns, many with worldwide operations. The Board also has many Associates among labor unions, colleges and universities, government agencies, libraries, and trade and professional associations.

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EXECUTIVE SUMMARY

The most demanding challenge facing America's leadership today is to restore this country's competitive position in the global marketplace. The pattern of the last fifteen years -- slowing productivity growth combined with growing competition from foreign producers -- has led to record trade deficits, a decline in real earnings of American workers, and a stagnant standard of living. While there are many reasons for the erosion of the U.S. competitive position, there is a growing national consensus regarding the underpinnings of competitiveness. One area of consensus is that U.S. investments in research and education will be critical in the long-term as the United States seeks to maintain and improve its competitive position in the world economy.

In an effort to assess the health of the U.S. research system, The Conference Board and the National Governors' Association, with the support and participation of the National Science Foundation, undertook a joint project. The project solicited the views of the nation's Governors, senior officers of U.S. companies, and presidents and deans of U.S. colleges and universities on the relationship of U.S. competitiveness to our human resource base and research and development capacity. The views of these key leaders were obtained through a survey and three regional meetings held in April, 1987.

The study focused on three primary topics: the adequacy of our human resources and their relationship to our ability to compete; U.S. investment in research and development; and technology transfer, i.e. the ability to transform research findings into new products and processes.

Marshalling Human Resources

Education was viewed by all three groups -- business, academia, and government -- as the key to the nation's competitiveness. While recognizing that one of the competitive strengths of the United States has been its human resources, the participants expressed concern regarding the quality of science, engineering, and mathematics education today. Although this concern applied to all levels of education, greatest concern focused on the K - 12 level.

At the university level, attention focused on the need for state-of-the-art facilities and equipment. Both business and state government officers supported the view of university officials that investment is sorely needed in laboratory instruments and buildings. There was less concern with the quality of undergraduate instruction than the preparation of undergraduate students in the sciences and mathematics and concern was expressed regarding the ability of colleges and universities to continue to attract and retain qualified faculty.

Business executives emphasized the need for high-level technical training, continuing education and job retraining. Pointing out that workers at every level can no longer expect to graduate from school with a skill that will last a lifetime, the business respondents emphasized the importance of maintaining a flexible workforce. While university officials agreed with this assessment, opinion was divided with regard to whether industries, community colleges, or universities should have responsibility for providing continuing education and training.

Participants recommended that science and mathematics education be improved by:

- improving the quality and quantity of teachers at the K - 12 level through the use of scholarships, grants and loans;
- changing certification requirements to allow engineers, physicists, and mathematicians to become certified to teach in the K - 12 grades;
- providing specialized school settings that emphasize math and science;
- increasing the involvement of the business community in K - 12 education; and
- generating greater corporate support for universities by participating in student cooperative programs, providing staff members to act as adjunct faculty, and donating funds and equipment to university laboratories.

Investing in Research and Development

With regard to U.S. investment in research and development, over half the respondents believed that increased support for civilian basic research is critical to the future competitiveness of the U.S. economy. There was some debate on whether or not the nation's current defense buildup might be draining scientists and engineers from the civilian sector, and whether this drain has an impact on the nation's competitiveness. A majority of those who expressed themselves on this issue thought that this trend was having a distinctly negative, if unmeasured, impact on America's ability to remain competitive in the civilian goods sectors. The survey respondents, however, did not believe that the concentration of research and development resources in the defense sector was a critical issue affecting competitiveness.

An interesting difference emerged from the survey in how much importance university officials placed on research and development resources as an issue affecting U.S. competitiveness as opposed to the competitiveness of their university. When asked to rank six major issue areas -- human resources, research and development resources, fiscal and monetary policy, federal regulatory policy, and technology transfer -- the university respondents ranked research and development resources first in terms of its impact on the university's competitiveness but sixth in terms of its impact on the nation's competitiveness. Business and state officials both ranked research and development resources as third in importance in regard to the nation's competitiveness.

The study participants agreed that in order to meet the challenge of economic competitiveness, the United States as a nation must not only make a commitment to its research system, but redefine the relationship between government, universities and businesses in the conduct of research and the use of : search findings. The study focused specifically on the new industry/ university research partnerships being created and sought to answer the following questions: what is the level of commitment on the part of both businesses and universities to these new partnerships? How effective do the respondents feel these joint efforts have been? What obstacles have been encountered in implementing university/industry programs? What steps could be taken to improve such partnership arrangements? What is the opinion of business and university leaders regarding state efforts to promote partnerships?

The concept of university-industry research partnerships and state efforts to promote such partnerships generally received high marks, but the study participants outlined a number of difficulties in their implementation. Both business and university officials stressed the need for greater corporate involvement. Industry, they indicated, is not committing its "best and brightest" scientists and engineers to these joint ventures. Some university officials also expressed reservations regarding the expectations being placed on these new partnerships to produce short-term economic development results.

There was general agreement that the new university-industry partnerships are experimental and that there is a need to monitor the outcomes of these efforts and assess their effectiveness.

In spite of business' support for industry-university partnerships, slightly more than half of the business respondents did not believe that cooperative research among industries and universities would have a critical impact on U.S. competitiveness and even fewer, approximately one-quarter, believed it would have a critical impact on the competitiveness of their firm. In contrast, over 80 percent of the state officials and two-thirds of the university respondents believed that cooperative research among industry and universities will have a critical impact on U.S. competitiveness.

Measures suggested for encouraging the growth of university/industry cooperative research include:

- Modification of existing anti-trust restrictions to encourage research and development joint ventures.
- Expansion of the number of technology centers.
- Provision of direct federal financial support for certain industry-university partnerships.
- Establishment of multi-industry, multi-disciplinary research parks.
- Alteration of laws to allow faculty members to take equity positions in research and development joint ventures.
- Development of uniform terms and contracts for joint ventures.

Creating an Innovative Environment: Getting Ideas to Marketplace

The final issue examined was technology transfer, the ability to apply new research findings in the marketplace. Business respondents do not believe technology transfer to be a critical issue affecting the nation's competitiveness. A review of the survey responses, however, indicates that the term technology transfer covers a wide array of issues some of which were identified as areas of serious concern. One such issue, for example, was the excess time lag in the commercialization of technology by business. Several meeting participants argued that the United States has not had a significant problem with commercialization -- that is, bringing a product to market -- but that it has experienced problems involving production and marketing, i.e., being able to produce a high-quality product at a competitive price.

Respondents from all three sectors believe that business' lack of long-term goals and vision has hindered the commercialization of U.S. technology. The business community was faulted, by its own representatives, for lack of patience, and for focusing on the next quarter's profits rather than the potential payoff from long-term investments in product development.

With regard to state programs, the business and university officials indicated a greater awareness and use of the programs that support research and development rather than those designed to assist in commercialization. The fact that business officials exhibited less interest in commercialization assistance programs may reflect the fact that the majority of the business respondents represent large firms, firms which have access to in-house technical expertise. A breakdown by size of firm shows that smaller companies did, in fact, show a greater degree of interest in the state commercialization assistance programs.

Specific suggestions for improving commercialization include:

- Development of more accurate indicators of technology transfer so that U.S. strategists have a better grasp of the dimensions of this problem.

- Increased interaction between technologists at primary manufacturing firms and those in supplier firms.

- Development of a cadre of technology transfer agents or mechanisms that will permit entrepreneurs to acquire and commercialize technology discoveries unused by either major laboratories or university research centers.

- Provision of specialized advice and technical support for small firms seeking to commercialize leading-edge technologies.

Conclusion

The industry, university and government leaders participating in the study agreed that science and engineering research and education have in the past, and will continue in the future, to play a crucial role in determining U.S. competitiveness. They further agreed that for the most part, the United States has a healthy and vibrant research and education system. Yet to maintain its competitive position and retain its technological leadership in the face of increased investment in research and education by our foreign competitors, the United States must continue to increase its investment in these areas.

The study participants identified a number of areas for improvement. These include science and mathematics education, university/industry cooperative ventures, and greater commercialization of research findings. The study also revealed, however, that much of the change that must occur is long-term in nature. Demographic factors and the increasingly technological nature of the modern economy, for example, will require a long-term perspective of our human resource needs, with greater emphasis on life-long education and retraining. In addition, changes in the nature and conduct of research are requiring universities, industry and government to change the way they operate and how they relate to each other. Such changes will not be achieved overnight.

In addition to determining the views of business, state government, and university officials on research, education, and competitiveness, the study raised a number of issues that merit further consideration. First, what actions should be taken to improve science and mathematics at the primary and secondary school levels? Second, demographic changes and a decline in the number of American students pursuing science and engineering degrees will necessitate increased involvement of women and minorities in science and engineering. How is this to be achieved? Third, how can long time lags in the commercialization process be reduced? Fourth, university/industry partnerships should be evaluated and their performance tracked over time. By what criteria do we judge their performance and their contribution to the generation and transfer of knowledge?

Lastly, future partnerships require redefinition. What is the relationship between state initiatives and federal efforts regarding research and development? Are state/federal partnerships needed, and if so, how should they be structured? How would a restructuring affect the private sector and the academic community? These are questions that should be addressed if the United States is to meet the growing economic challenge.

INTRODUCTION

The most demanding challenge facing America's leadership today is to restore this country's competitive position in the global marketplace. The pattern occurring in the last fifteen years -- slowing productivity growth combined with growing competition from foreign producers -- has led to record trade deficits, a decline in real earnings of American workers, and a stagnant standard of living. While there are many reasons for the erosion of the U.S. competitive position, there is a growing national consensus regarding the underpinnings of competitiveness. One area of consensus is that U.S. investments in research and education will be critical in the long-term as the United States seeks to maintain and improve its competitive position in the world economy.

The ability of U.S. firms to compete in world markets depends critically on their ability to continually generate new ideas and use new technologies. To remain competitive, the United States must remain at the cutting edge of science and technology and adopt and implement the new technology developed. The United States has long been considered the world leader in advancing knowledge in the areas of science and technology. Recently, this leadership has been questioned.

A 1986 survey conducted by The Conference Board showed that leading U.S. companies were deeply concerned with government policies that would spur U.S. research and development and improve their firm's ability to compete globally. Survey respondents (public affairs officers) placed "Technology and Economic Competitiveness," on the list of the "10 most important" issues facing their companies today.

In an effort to assess the health of the U.S. research system as viewed by the nation's Governors, senior officers of U.S. companies, and presidents and deans of U.S. colleges and universities, and to propose ways to improve U.S. competitiveness by improving our research and development capacity, The Conference Board and the National Governors' Association, with support from the National Science Foundation, undertook a joint project.

This project, which included a survey of key policymakers and three regional meetings, was designed to solicit the views of these leaders from state government, industry and academia, on issues of science and technology in general and to obtain their assessment of state research and technology initiatives. The study was also designed to provide new insights and an understanding of how the roles of state and federal governments, industries, and universities need to change in order to respond to the competitiveness challenge.

The focus on the state role reflects the recognition that competitiveness is not just a federal concern. (See APPENDIX III.) There is increasing commitment on the part of the nation's Governors to promote economic development through support for education, research and technological development. State governments are critically situated to encourage and facilitate the process of technological innovation; they directly influence the quality of elementary and secondary education and employment and training that is essential for the development of human resources in scientific and technological disciplines. They support the vast majority of the nation's public institutions of higher education where most university research and development takes place.

In many cases, state governments provide a critical link to the private sector, acting as catalysts to encourage the application of research findings. Over the past five years, state governments have, in fact, provided funding for research and development projects, sought to improve research facilities at state colleges and universities, set up a host of programs designed to help inventors and entrepreneurs start new businesses, help existing firms adopt new technological processes, and generally improve the link between the performers and users of research.

To meet the challenge of economic competitiveness, the United States as a nation must make a long-term commitment to its education and research system. But we will achieve the goals of maintaining the leadership position in science and technology and speeding the diffusion of new knowledge and technology throughout the economy only if government, universities, and industry work together. This will require an openness on the part of each party and a willingness to redefine relationships and experiment with new ways of doing business. This report contains the suggestions of state government, business, and educational leaders on how best to do this.

MARSHALLING HUMAN RESOURCES

No discussion of competitiveness can continue for very long without focusing on the issue of America's human resources and their relationship to our ability to compete. The National Commission on Excellence in Education in their landmark study, A Nation at Risk, concluded:

> "History is not kind to idlers...we live among determined, well-educated, and strongly motivated competitors...America's position in the world may once have been reasonably secure with only a few exceptionally well-trained men and women. It is no longer."

In past decades, one of the competitive strengths of the United States has been its human resources. The quality of our scientific and engineering professions, coupled with a highly skilled work force, have played a critical role in supporting U.S. technological innovation. Recent trends, however, are disturbing. The National Science Foundation reports, for example, that the United States no longer holds an advantage over our trading partners in the number of scientists and engineers per capita. In addition, the numbers of students available to pursue science careers will decline from now until the 1990s.

In addition to these trends, concern has arisen regarding the quality of science and technical education at the elementary, secondary, and college level. A recent report by the National Science Board found serious deficiencies in undergraduate science, mathematics, and engineering education.

These include:

- serious deterioration in laboratory instruction;
- faculty members unable to update their disciplinary knowledge and to make use of computers and other advanced technologies; and
- courses and curricula which are out of date, unimaginative, poorly organized for students with different interests, and fail to reflect recent advances in the understanding of teaching and learning.

In order to assess the quality and availability of both our existing and future scientific and engineering personnel, information on human resources was collected in the survey and discussed at the regional meetings. Far and away, human resources emerged as the most critical factor affecting the nation's competitiveness.

The survey respondents were asked how the various issues examined in the study--human resources, research and development resources, technology transfer, and federal trade, monetary, and regulatory policy--ranked in terms of their firm's, university's or state's competitiveness and then how they would rank these same issues as affecting the nation's international competitiveness. All three groups ranked educational and human resource policies and practices as the key issue affecting the nation's competitiveness. Executives surveyed also indicated that human resources is the key issue affecting the competitiveness of their individual firms.

The ranking selection of state officials differed somewhat. State government officials, when considering these same factors as they apply to their state's competitiveness, rank trade issues of primary importance and give human resources only a ranking of fourth. But when asked how they believe the issues apply to the nation as a whole, they move human resources to the top-ranked position.

The view that education and human resource development is the key to the nation's future competitiveness was reiterated at the regional meetings. "The only truly durable response to competitiveness is education," said one chemical company executive. "All other things must follow after it. Even innovation and research and development cannot last long without a good base in education."

Meeting Future Needs

Having identified human resource needs as an area of critical concern, the survey respondents were asked to identify the specific human and educational resources thought to have the most significant impact on our nation's competitiveness. The respondents were asked to rank each issue as of critical, moderate, slight, or no impact on competitveness. Table 1 shows how the respondents rated these issues. The respondents were also asked to consider the effect of these issues on their individual business, university, and state. These results are shown in Table 2.

Greatest emphasis was placed on the need to develop and maintain an adequate supply of science, engineering, and technical personnel, with 90 percent of the business respondents, 97 percent of the university respondents, and 86 percent of the state respondents giving this issue a critical rating in the survey. Preparation of elementary and secondary students in science and mathematics also received a critical ranking followed by a concern with the supply of science teachers at all levels. Two-thirds of the business respondents also felt that the preparation of undergraduate students in science and engineering curriculum was a critical issue.

The discussion at the meetings reiterated these concerns and raised several additional ones. First, there was widespread agreement on the need for increased attention to K - 12 education in general and to science and mathematics education at this level in particular. Second, there is a need for continued investment in our university systems. Third, the meeting participants identified a need for retraining and continuing education, an area not identified as a high priority concern in the survey. There was very little difference in opinion among the business, university, and government sectors in regard to these issues.

Closing the Personnel Gap. Most of those surveyed and attending the meetings hold to the belief that the nation will suffer from a shortage of qualified engineers, scientists, and technicians in the near future; and they have suggested various remedies for this shortage. This was, in fact, the human resource issue rated most important to the survey respondents. In general, respondents from both the business and university communities believe that market forces -- principally higher salaries for scientists, engineers, and technicians -- will solve the shortage issue. The study participants also believe that improvements in education and special incentives may be needed to ensure an adequate supply of skilled workers.

Table 1

Human Resource Issues
Percentage of Respondents Rating Issue as Critical to the Competitiveness of U.S. Economy

	Business	University	State
Developing and maintaining adequate supply of science, engineering, and technical personnel	90%	97%	86%
Preparation of elementary and secondary students in science and mathematics	81	86	77
Supply and quality of science teachers at all levels	80	84	64
Preparation of undergraduate students in science and engineering curriculum	63	71	50
Developing public understanding of science and engineering	39	43	33
Availability and value of continuing education programs	32	33	33
Increased reliance of U.S. industry on foreign student graduates of U.S. universities	32	41	32
Cost-benefits of obtaining a science or engineering education vs. other graduate training	26	25	15

Source: Unless specified, all tables in this report are based on the National Governors' Association/ Conference Board survey on the role of research and education in economic competitiveness, 1987.

Table 2

Human Resource Issues
Percentage of Respondents Rating Issue as Critical to the Competitiveness of Their Company, University, or State

	Business	University	State
Developing and maintaining adequate supply of science, engineering, and technical personnel	77%	58%	77%
Preparation of elementary and secondary students in science and mathematics	58	68	79
Supply and quality of science teachers at all levels	56	68	74
Preparation of undergraduate students in science and engineering curriculum	58	53	49
Developing public understanding of science & engineering	22	30	30
Availability and value of continuing education programs	24	29	51
Increased reliance of U.S. industry on foreign student graduates of U.S. universities	15	20	19
Cost-benefits of obtaining a science or engineering education vs. other graduate training	24	18	17

Some of the specific suggestions include:

- Promote the economic advantage of science and engineering education by advertising the availability of technically-oriented jobs in the private sector.

- Provide expanded financial assistance to undergraduate students majoring in science and engineering.

- Subsidize Ph.D. candidates in science and engineering who agree to teach for a two - to three-year period after graduation.

- Improve the quality and availability of science teachers in the K-12 grades by increasing salary levels for these teachers.

- Provide special scholarships for science teachers in training.

The majority of these suggestions deal with improvements in the educational system and are discussed in greater detail below.

Improving K-12 Education. The senior vice president of a multinational communications firm outlined some of the factors that have raised concern regarding our education system:

> "It is well known that 25 percent of our American students will not even graduate from high school and, of those who do graduate, many lack fundamental reading, writing, and mathematics skills. Add to this the fact that the National Science Teachers Association reports that 50 percent of all science and mathematics instructors probably are not qualified to teach. Meanwhile, businesses need entry-level employees, not just with a firm grasp of the basics, but with high-order technical, analytical, and problem-solving skills."

In addition to the need to improve the nation's K-12 education system, a number of specific concerns also surfaced. First was the need for scientific literacy, i.e., a general understanding of the role and contribution of science. The meeting attendees agreed that the majority of Americans will need to be science-literate to operate in our society -- although only 39 percent, 43 percent, and 33 percent of the industry, university, and state survey respondents, respectively, identified developing public understanding of science and engineering as a critical issue affecting U.S. competitiveness.

Second, in order to interest young people in science and engineering careers, the study participants believe that the nation must begin to develop this interest at the very early grade levels. Demographic changes over the next ten years indicate that, in order to produce a sufficient supply of scientists and engineers, the United States will have to greatly increase the proportion of students going into such areas and attract previously untapped sources, namely minorities and women. One way to achieve these goals is to focus on students at the K-3 level.

The program administrator for curriculum in one western state says:

"We're trying to start in kindergarten, because high school is way, way too late... By then, the attitudes are formed, directions are pretty well ascertained, and its too late to have much impact on the kids if they haven't already got some kind of a bent toward science and technology and scientific literacy."

The participants also felt that efforts to recruit minority students should start as early as possible. Lack of role models was identified as a problem in trying to interest more minority students in science and mathematics. In the State of Washington, for example, a state official reported, "No Black or Hispanic will graduate from a teacher preparation program for mathematics and science in the next four years."

Supporting Universities. In discussing the present condition of undergraduate education, the meeting participants identified three primary needs. First is the need to attract qualified faculty. Second is to ensure that graduates have the skills required by business, and third is greater investment in facilities and equipment.

Colleges and universities are faced with the problem of seeking to attract qualified faculty at salaries competitive with the private sector. This will become increasingly critical as current faculties age and the supply of new, competent faculty decreases.

With regard to the skills level of today's college graduates, the senior vice president for one of the nation's largest banks reports that her division (data processing) does no entry-level hiring of recent college graduates. "The reason is that they are not skilled in anything that we can use right away." Many secondary schools are building EDP systems technology into their curriculum, and while this is encouraging, the executive said, "it may not be enough." She recommends a continued focus on the university system in order to ensure that it is not only turning out quality students, but that they possess skills that meet the need of the market.

Investment in facilities, equipment, and structures is also needed.' The academic dean at one western college reported "We haven't, with the exception of computers, replaced a single major piece of equipment since the college was completed over ten years ago." And the president of a major engineering school agreed for the need of investment in facilities and equipment, saying that a major concern of public research universities in his state is a facilities concern.

Need for Continuing Education and Retraining. In the past, successive generations came into the workforce with an educational grounding and a set of skills that they would find useful for most of their lives. While the importance of a basic education remains, the skills now required for continued employment are changing so rapidly that continuing education is essential; consider that the half-life of a software engineer, i.e., the time during which the cutting-edge knowledge gained from previous education will become obsolete, is estimated to be two and a half years and that of an electrical engineer is five years.

There was recognition among the meeting participants that demographic and technological factors will require a fundamental shift in the way the nation thinks about careers and training. Investment in human resources, which has focused traditionally on training new entrants to the workforce, is going to have to be refocused on the continuing education and retraining of experienced workers to maintain currency of skills.

Twenty-six state government survey respondents report skills retraining programs for production, technical, or research staff. Approximately 45 percent of both the industry and university respondents report they are aware of these programs, although only 23 percent of the businesses and 27 percent of the universities report having used them. The discrepancy between the importance placed on skills retraining by the meeting participants, as opposed to the survey respondents who did not rank skills retraining very highly, may reflect the fact that the survey respondents did not consider ongoing education in the same category as skills retraining.

While recognizing the need for continuing education, the meeting participants also identified several obstacles to such programs. It was suggested, for example, that vocational and technical schools lack the necessary resources to respond to changing skills requirements. Our national tax policies create disincentives for employees who seek educational and occupational mobility through their own self-initiated training efforts. There is little real incentive for employers to provide retraining activities in the workplace. It was argued further that our unemployment insurance system contains few incentives for displaced workers to seek retraining.

The meeting participants concluded that we must redefine the roles of industry and academia in retraining. One executive suggested perhaps some of the institutions that have traditionally considered themselves as "providers of education," need to rethink whether or not their best role for the next decade may be in the retraining area.

Government's Role

As state governments have primary responsibility for funding K-12 education, they will play a critical role in meeting human resource needs. At the regional meetings, both Governor Booth Gardner of Washington and Governor Thomas Kean of New Jersey emphasized the fundamental role that governments play as educators. Governor Gardner stated: "The basic service we provide (among many others -- but the primary service in terms of where our money goes and what I think is most important) is education. That is the foundation. We can do everything else we want in all other areas: in agriculture, trade and economic development, and a number of other areas; but if we don't have a solid foundation, all our other work is for naught."

State Education Initiatives. Governor Kean referred to the leadership role of the states in a national educational reform movement which is sweeping the country. "I'm talking about higher standards for children, I'm talking about higher standards for teachers, and we are pushing at every level." Many of these state education reforms are already addressing the issues raised by the meeting participants and the survey respondents regarding needed changes at the K-12 level.[2]

The issue of differential salaries for math and science teachers and changes in certification requirements were discussed at some length by the meeting participants in Washington. One state official pointed out that teachers within the K-12 system are strongly opposed to differential pay scales. He added that, in his state, educational officials are trying to find other incentives, such as staff development, special equipment, and additional privileges. He added that one way in which the quality of science and mathematics education can be improved is by providing money for high school science labs.

It was also suggested, however, that in spite of the problems associated with differential pay, it might someday be implemented. "I wouldn't be surprised if the understandable resistance to differential pay scales in the professional education community is not overwhelmed by political and societal concern in the foreseeable future," said one of the meeting panelists.

With regard to teacher certification, there were two suggestions made. The first was to increase the number of science courses required for certification as a science teacher and the second was to change requirements to allow engineers, physicists, and mathematicians to become certified to teach in the K-12 grades; for example, by completing a one-year graduate teaching program as opposed to taking two to three years of education courses.

A number of states are, as noted, already addressing the issues raised by the meeting participants regarding K-12 education. Additional possible actions for state government include:

- help local districts enhance math and science curricula in K-12 system by improving the quality and quantity of teachers in these critical areas including the use of scholarships, grants and loans, and alternative certificate paths for teachers;

- provide more specialized school settings that emphasize math and science, including summer institutes for promising students;

- promote the accelerated movement of students between secondary and post-secondary institutions for advanced learning; and

- generate more scholarships for students going into engineering, especially manufacturing and the sciences, by leveraging resources from the private sector.

State governments also have a role to play in retraining and continuing education, although their role here is probably subordinate to that of the business and university communities. States can, however, use state community college systems and vocational and technical schools to provide the training and retraining needed for a highly flexible workforce.

Finally, the states have a responsibility to develop programs to encourage minorities and women to enter science and mathematics programs. As Governor Kean pointed out, "an increasing number of the children we are trying to educate are Black or Hispanic. It is estimated that one out of three children in our public schools will be minority children by the year 2000. We simply have to do a better job of bringing these school children and these citizens into the mainstream of American life." In the state of Washington, a program called Even Start has been implemented to address this need. The program works with parents so that they will become literate enough to be able to understand what their children are learning in grades K-3 underscoring the recommendation of the meeting participants that the best way to interest young people, including minorities, in mathematics and science is to begin at the K-3 level.

Federal Support for Science and Mathematics Education. Although the major responsibility for education rests with the states, there was considerable comment by survey respondents on the need for increased federal support at the K-12 levels. Forum participants indicated their support for ongoing federal activities designed to improve the quality of science, mathematics, and engineering education.[3]

An additional proposal made at the Michigan meeting was for NSF to fund faculty summer positions in industrial laboratories. It was felt that such internships would help to improve the skills of both secondary- and college-level teachers.

The Role of Business

In the past thirty years, corporate support of colleges and universities has risen from approximately $40 million to more than $1 billion. In addition to the direct support of colleges and universities, business corporations currently provide an estimated $350 million in other educational aid -- scholarships and fellowships to students, grants to precollege institutions, donations of equipment, and support of many educational activities and organizations.

The business executives participating in the meetings believed that the business community should become more active in supporting K - 12 education and should increase its participation in university-based programs. One business executive used the example of a math and science center established with industry support.

> "Last year, our company gave $2 million to form and endow a math and science center. This is a brand new center containing the latest in technology for education of high-school students. In addition to providing an accelerated and very high-quality education for 300 students on a continuing basis, it has an outreach function that will increase and improve the quality of science education and awareness in the entire community.
>
> "I think that this kind of modest investment will do more toward improving this country's technological competitiveness than anything else we could have done with the money, including the worthwhile endowment of one or more university chairs."

The meeting participants agreed that corporations have a major role to play in meeting retraining and continuing education needs. There was recognition, in fact, that most large corporations have very strong education programs which include tuition refunds and time off to get advanced degrees in addition to the massive internal education programs that are offered. A participant pointed out however, that you have to make a very clear distinction between the very large corporations that in terms of training have the economies of scales to do it in-house and the small firms, which have neither the scale nor the resources to provide employee training on a continuing basis.

Corporations also have specific ideas on how they can assist universities. There is a striking degree of agreement with the views expressed by their university colleagues. The primary ways, rank ordered, are:

- Through participation in student cooperative programs.
- By providing staff members to serve as adjunct faculty.
- Through funds and equipment donated to university laboratories.

Several firms in Washington and Oregon suggested that business could assist in curriculum development. "We are applications-oriented. We can help university engineering departments stay in a practical venue by participating in curriculum planning and providing insight into industry's technology needs." A Midwestern company wrote "We would like to assist in teaching and provide hands-on experience with our advanced equipment."

Several firms in Minnesota, Michigan, Montana, and Illinois recommended expanding student internships, visiting professor programs, industry supplied part-time teachers and two-way sabbaticals. An Illinois manager writes "We can help by establishing strong, informal communications channels between universities and our R&D laboratory. This can be accomplished by joint research programs, joint seminars, informal visits and grants to faculty in important, emerging technology areas."

NOTES

1. Two major recent reports, the White House Policy Council (Bromley-Packard) report on the health of U.S. universities and a report published by the Government/University/Industry Research Roundtable of the National Academy of Sciences, find widespread agreement that there is a need to modernize deteriorating and obsolete research facilities at universities and colleges. The latter report estimates that unmet demand for new facilities construction and renovation of research facilities will range from $5 to $20 billion in the next ten to twenty years.

2. States have raised standards, expanded the number of mathematics and science courses required of students, increased the amount of time devoted to mathematics and science, established more rigorous graduation requirements, and inserted computer literacy into the curriculum. In addition, some states have established special science and mathematics high schools, provided scholarships for students to encourage pursuit of math and science undergraduate degrees, and instituted recruitment programs for science and math teachers. (See APPENDIX III.)

3. The National Science Foundation's fiscal 1988 budget request proposed several initiatives to improve science and engineering education at pre-college, college, and graduate levels. Pre-college activities, which include hands-on research experience to encourage science, mathematics, and engineering careers through enrichment activities for talented high school students and development of improved teaching materials, would be funded at $68 million under the new budget. An additional $70 million would be used to improve the quality of undergraduate instruction.

   The Department of Education also provides support for improving science and mathematics education. Funded at $80 million for fiscal 1987, this program provides grants to states to offset part of the cost for training and retraining mathematics and science teachers at the secondary level.

   Federal agencies, for the most part, support graduate and post-doctoral level education through research project support and competitive fellowships. In 1985, NSF, the National Institutes of Health, the Department of Defense, and other federal agencies, supported 20 percent of all full-time engineering and science graduate students in doctorate-granting institutions.

   NSF also operates programs designed to encourage promising young scientists and engineers to remain in academic careers, e.g., Presidential Young Investigator's Award Program, and to encourage women and minority students to pursue science and engineering careers.

INVESTING IN RESEARCH AND DEVELOPMENT

U.S. investment in research and development has been credited with making the United States the world leader in science and technology and with the related growth in economic productivity. United States spending on research and development in 1987 is estimated to be $125.2 billion. Roughly half of these funds are provided by the private sector, with the federal government providing the majority of the remaining half, and states and other sources providing 3 percent of the total.

There is concern, however, that the United States is losing its dominance. First, while U.S investment in research and development is the highest of any country in the world, U.S. investment in civilian research and development as a fraction of GNP is less than that of Germany and Japan. In 1983 the United States invested 1.91 percent of GNP in non-defense R & D while Germany invested 2.47 percent and Japan 2.60 percent. The federal investment in applied research and development in non-defense areas is estimated to have declined by 17 percent and 55 percent, respectively, in constant dollar terms between 1980 and 1985. Business support of applied research during the same period grew at an average annual rate of 10.2 percent in constant dollars.

Second, the proportion of our trading competitors' workforces engaged in research and development has increased sharply since 1965 -- and is beginning to approach U.S. levels e.g., Japan and Germany have doubled their research and development workforces during this period.

These factors raise concern regarding the United States' ability to not only maintain its leadership position but to gain on our competitors. The survey and the meetings collected information on what needs to be done to ensure that the United States maintains its competitive edge in research and development.

Meeting Research and Development Needs

The survey respondents were asked to indicate the importance of research and development resources to U.S. competitiveness. An interesting difference emerged from the survey in how much importance university officials placed on research and development resources as an issue affecting U.S. competitiveness as opposed to the competitiveness of their university. When asked to rank six major issue areas -- human resources, research and development resources, fiscal and monetary policy, federal regulatory policy, and technology transfer -- the university respondents ranked research and development resources first in terms of its impact on the university's competitiveness but sixth in terms of its impact on the nation's competitiveness. Business and state officials both ranked research and development resources as third in importance in regard to the nation's competitiveness.

The survey also collected information on five issues affecting the allocation and use of research and development resources. The respondents were asked first to indicate whether they believe that the concentration of research and development resources in the defense sector was having an impact on competitiveness. They were also asked whether or not they believe that increased support for civilian basic research would have a strategic impact on the U.S. economy.

The respondents were also asked to indicate the importance of access to state-of-the-art research and development equipment and facilities, the significance of increasing industrial support for university-based research, and the importance of cooperative research to the competitive position of the United States and their individual business, university or state. Tables 3 and 4 show how these issues were rated by the respondents.

Increased Support for Research and Development. Over half the respondents believe that increased support for civilian basic research is critical to the future competitiveness of U.S. economy. Fifty-seven percent of the business leaders, 67 percent of the state officials, and 72 percent of the university officials believe that increased support for university-based civilian research is critical and approximately 50 percent of each group believes that increased support for civilian basic research by industry is critical to competitiveness. Approximately 60 percent of the state and university respondents indicated that increased industrial support for university-based research is also a critical issue affecting U.S. competitiveness. However, only a third of the business respondents shared this view.

Although all three groups believe that greater investment in civilian research and development is a critical issue affecting U.S. competitiveness, only one-third of the business and university officials regard the concentration of research and development resources in the defense sector as having a critical impact on U.S. competitiveness. State officials placed greater emphasis on this issue with nearly half indicating that this factor has a critical impact on the nation's competitiveness.

Access to Facilities and Equipment. Many of the business leaders questioned believe that in order to make significantl gains on our competitors, industry needs more access to state-of-the-art equipment. Nearly 80 percent of the repondents ranked this as either of critical or moderate importance. Many university leaders agreed with their business counterparts, citing what they describe as "the deplorable state of university research and development equipment." Several respondents commented that the equipment science and engineering students use is very often older than the students themselves. University leaders would like more sharing of equipment with industrial laboratories and, naturally, would encourage business to make equipment donations to local colleges and universities. State government officials also placed priority on the need for universities to have access to state-of-the-art research and development facilities and equipment.

Importance of Cooperative Research. State government officials placed highest priority on cooperative research among industry and universities with over 80 percent rating this issue as critical to U.S. competitiveness. Less than half of the business respondents and two-thirds of the university respondents agreed, however, that the issue was critical. In addition, even fewer of the businesses rated either cooperative university/industry research as critical to the competitiveness of their company. This may indicate that many business leaders, and a number of university officials, do not perceive a pressing need for joint university/industry ventures.

Table 3

Research and Development Issues
Percentage of Respondents Rating Issue as Critical to the Competitiveness of the U.S. Economy

	Business	University	State
Access to state-of-the-art R&D equipment and facilities			
A. by industry	69%	81%	68%
B. by universities	66	78	78
Increased support for civilian basic research as performed			
A. by industry	46	57	50
B. by universities	57	72	67
Importance of cooperative research:			
A. among industries	44	44	45
B. among industries and universities	45	67	83
Significance of increasing industry support for university-based research	34	59	62
Concentration of research and development resources in the defense sector	34	35	48

Table 4

Research and Development Issues
Percentage of Respondents Rating Issue as Critical to the Competitiveness of Their Company, University, or State

	Business	University	State
Access to state-of-the-art R&D equipment and facilities			
A. by industry	52%	46%	65%
B. by universities	38	71	83
Increased support for civilian basic research as performed			
A. by industry	25	26	49
B. by universities	28	64	65
Importance of cooperative research:			
A. among industries	26	20	35
B. among industries and universities	27	52	74
Significance of increasing industry support for university-based research	20	52	54
Concentration of research and development resources in the defense sector	10	10	35

In the view of state officials, one of the barriers to innovation is the traditional view of American industry. One of the goals of many state programs, therefore, is to change these perceptions. The survey indicates that attitudes must change if cooperative ventures are to play a major role in supporting U.S. research and development.

The Changing Nature of Research and Development. Participants at the state meetings were asked to comment on what they saw as necessary components of the effort to rebuild research and development resources. There was general agreement among the meeting participants that the issue is not whether or not we are spending sufficient dollars on research and development. The vice-president for research and development of an automotive company expressed it this way: "What is more important probably is the quality of the research, the attitudes of the people that do it, and the direction in which it is aimed." The participants did agree that the nature of research is changing, thus there is a need for the performers and users of research to respond.

One change cited by the study participants involves the fact that research is becoming more complex, more capital-intensive, and dependent on sophisticated instrumentation and computers. This change was reflected in the survey results noted above, with 80 percent of the business respondents identifying access to state-of-the-art equipment and facilities as of either critical or moderate importance to U.S. competitiveness.

A second change noted is that research is becoming increasingly interdisciplinary in nature. While it has always been true that new fields are created at the boundaries of existing ones, the meeting participants suggested that this is now happening at a much more rapid pace. The president of a major pharmaceutical company attested to the interdisciplinary nature of his industry when he reported: "We have within our biological department no less than fifteen (separate) disciplines represented."

A third change is a recognition that the line between basic and applied research is blurring and that there is a need for greater interaction between basic research and technology development. One meeting participant said, "We have come to realize that the innovation process is not a sequential process, (pure science leading to technology and to economic opportunity) but involves strong coupling - both ways - between technology and basic science. Each is stimulated by and dependent on the other."

One response to the changing nature of research and development has been the creation of new institutional relationships between businesses -- the primary users of research -- and universities, where most basic research occurs.

Redefining Roles for Government, Industry and Universtities

The study participants agreed that in order to meet the challenge of economic competitiveness, the United States as a nation must not only make a commitment to its research system, but must redefine the relationship between government, universities and businesses in the conduct of research and the use of research findings. The study focused specifically on the new industry/university research partnerships being created and sought to answer the following questions: what is the level of commitment on the part of both businesses and universities to these new partnerships?; how effective do the respondents feel these joint efforts have been?; what obstacles have been encountered in implementing university/industry programs?; what steps could be taken to improve such partnership arrangements?; and what is the opinion of business and university leaders regarding state efforts to promote partnerships?

Research and Development Partnerships. In spite of the fact that business support for university/industry ventures appears mixed, the past several years have witnessed a major increase in the number of new university/industry research partnerships. For universities, these partnerships have been spurred by the prospect of additional research dollars at a time when federal dollars are in increasing demand. In addition, universities have benefited from donations of state-of-the-art equipment, and increased opportunities for both students and faculty to interact with industrial researchers.

Industry participation in these alliances has been motivated by its need to develop and adopt new technological processes and products quickly and to secure access to innovative researchers and fresh ideas. The rapid pace of technological change has encouraged industry to seek involvement in university research programs.

The chairman of one state's Commission on Science and Technology argued for the creation of academic, industrial research centers. "Academic industrial partnerships centered in universities can provide our industries with a proper arena for long-term strategic thinking away from some of the short-term pressures of the marketplace and day-to-day political considerations." Such centers give industry direct access to academic research excellence, as well as access to faculty and students. In return, business participates by becoming members of centers, donating equipment, sponsoring research, and, most importantly, involving its key people on advisory boards and in the conduct of the research.

The meeting participants shared the favorable view of the state officials regarding these new partnerships and suggested that close linkages between universities and industry are critical to the nation's future competitiveness. Many cite the special synergy that takes place when market-oriented industry scientists get together with their basic research-oriented university colleagues.

While less than half of the business respondents felt that joint university/industry research was critical to the nation's competitiveness, when asked specifically about their assessment of existing partnerships, the business responses were generally positive. Of the firms responding to the survey, four-fifths were aware of state initiatives to promote joint industry/university research projects and nearly two-thirds of the businesses have participated in such programs. Over two-thirds of the business repondents gave these programs a high ranking in their assessment of them. Three-quarters of the university respondents were aware of the programs and 57 percent had participated in them. The university respondents were also supportive of the programs with three-quarters giving them a high ranking in terms of effectiveness. Thirty-five states reported enacting joint industry/university initiatives, thirty-two of which are currently operational.

Joint Ventures Among Competing Companies. Joint ventures among competing companies were viewed very differently than were university/industry partnerships. One firm volunteered that it was generally opposed to joint ventures between competing companies because "such arrangements tend to retard the introduction of new technology to the marketplace."

A Washington-based company pointed out:

"Joint research and development ventures, particularly between competing companies, are often very difficult... and potentially illegal. It might be possible for government to establish university research and development funds that could be spent investigating specific areas of interest to industry. In such scenarios industry would, to a limited extent, be involved in directing the research effort."

An official at one Alabama university said:

"Universities would be more effective if they shied away from joint ventures that involve two or more competing companies. Industry is better served with bilateral agreements with university research sources.

An official at one Midwestern engineering college pointed out that: "Fostering cooperation among competitors can be tantamount to state-sanctioned monopolies, and it should not be encouraged."

On the other hand, several study participants called for further easing of anti-trust restrictions to allow joint research. Although legislation has been passed, allowing cooperative research, some business respondents expressed concern that such regulations are subject to change. An Indiana-based company stated that in its experience "the mere easement of anti-trust restrictions, in a generalized way, is not enough. We need specific relief from the risks we see on specific joint research and development projects. That easement should be specific and should be formalized."

Impediments to Partnerships. There was a recognition among the meeting participants that these new initiatives are challenging both universities and business to change in fundamental ways. A number of obstacles were identified which make true partnerships difficult to achieve. First, there is a belief that industry and university researchers are operating from very different perspectives -- what is sometimes referred to as the "two-culture" problem. The traditional attitude of many faculty members, which is also reflected in the university's incentive structure, is that their role is to discover knowledge for its own sake and to disseminate research findings by means of publications. Industry managers are concerned with commercial products and applications and protecting proprietary interests.

The director of a state university Research and Technology Park, outlined the following obstacles in the university setting which inhibit the transfer of basic research findings to the private sector.

"Consulting with industry is not an important criterion for promotion, merit increases, or tenure in the university system. In fact, most universities have explicit or implicit policies against it. The same is true with applied research and contract research with respect to industry. It is not encouraged and does not receive the same kind of positive evaluation that basic research does.

In addition, would-be faculty entrepreneurs are discouraged from taking equity positions and participating in a start-up venture, not only because their peers look down on it, but because state laws and university policies have regulations against it."

An officer of another university made the following comment:

"Publication continues to be a problem. It is the key to success in the academic research environment, but the restrictions associated with disclosure and patenting (both nationally and internationally) are viewed as interfering with the publishing process by most researchers."

But universities are not alone in setting up barriers to meaningful participation in joint research and development activities. A number of meeting participants suggested that industry involvement in these partnerships is often more symbolic than real. A common complaint heard is that industry does not commit its best people to such activities. One participant in a joint research and development center commented: "Here the Japanese were sending people equal to, or better than, the top five percent of their graduate students. The U.S. companies were sending people looking for a year to tide them over and who did not contribute very much."

A university official reported.

"Business and industry support joint research centers, but we have to be more successful at getting corporate scientists to participate. Companies will invest many millions of dollars in a center and then attend maybe two seminars. The Japanese will send twenty-three of their best young scientists, who take the trouble to learn our language and culture, and who give as much to the program as they take from it."

An executive of a large U.S. corporation contributing to a center also has problems with the quality of U.S. participants:

"We put in our $50,000 a year and we attended two seminars... The Japanese sent twenty-two full-time people to participate in the program for one year. We, U.S. industry, are very guilty of putting money where it counts, but then not participating fully in the education process."

In addition to either not participating or not sending the very best people, it was suggested that industry generally sends staff from their research unit, not senior people responsible for product development, manufacturing, and design functions. It was suggested that the lack of involvement of persons involved in these other functions, especially manufacturing, causes problems in terms of moving research findings into the marketplace.

A final issue that was raised is the ability of small businesses to participate in cooperative research ventures. A Midwest Center Director argues that:

> "Virtually all the cooperative programs that have been given a lot of publicity generally are targeted toward Fortune 1000 companies. Rarely do you find small companies, whether they're start-up or established companies, involved in cooperative research ventures. They don't have the capital and it is difficult for them to connect up with the universities."

This contention was upheld by the survey data. While 81 percent of the firms with 500 or more employees were aware of joint research programs and 71 percent had participated in joint ventures, only 54 percent of the firms with fewer than 500 employees were aware of the programs and only 35 percent had used them.

There was also concern expressed regarding the impact of university involvement in cooperative programs. Some university officials argued that the fundamental role of the university is education. If universities are to change and assume a strong economic development role, consideration must be given to how such efforts should be supported and how this mission fits in with the overall mandate of a university.

The Dean of Engineering at a major research university, which has a number of research centers, expressed concern that "the best and brightest faculty, young and old, are chasing money now. They are not chasing ideas.' An official from another university saw things quite differently. "With the center concept, it is the director, not the researcher, who focuses on writing proposals that go to various government agencies. Now the faculty researchers have more time to think without worrying about money."

<u>Making Partnerships Work</u> The survey respondents were asked to look ahead at what steps could be taken to encourage the growth of industry-university research and development ventures. Some of the most frequently mentioned steps and strategies include:

- Modify existing anti-trust restrictions to encourage research and development joint ventures.
- Expand the number of technology centers.
- Provide direct federal financial support for certain industry-university partnerships.
- Establish multi-industry, multi-disciplinary research parks.
- Change laws to allow faculty members to take equity positions in research and development joint ventures.
- Develop uniform terms and contracts for joint ventures.

The meeting participants agreed that effective mechanisms for interaction are needed and proposed fundamental changes in the behavior and incentive structures of both industry and academia. The business respondents recommended that university policies regarding faculty consulting, equity positions, and conflict of interest be reviewed, and that incentive programs to encourage the disclosure and patenting process need to be put in place. It was suggested further that universities must be given the financial resources to pursue these policies.

University reactions to these suggestions were mixed. One university official argued that the limiting factor today is not willingness on the part of the university to allow open communication. Rather. "it is the financial support of the university to prepare itself as a worthy collaborator" that is an obstacle. Another participant recommended the development of new organizations as a way to improve interaction between industry and universities. "What is needed are hybrid organizations, organizations that might be within a university or somehow related to the university."

Some of the university presidents reminded the regional meeting participants that much of industry's support may be too narrowly focused. That is, they said, aid to university research, should have fewer "strings" attached, i.e. should not be narrowly targeted to a specific technical goal. Sometimes they say, the restrictions on the aid they receive are so tight that the university scientists are unable to explore alternatives that, ultimately, might be more beneficial to industry sponsors.

There were also a number of recommendations regarding the involvement of private firms in cooperative ventures. Business must be willing to commit their "best and brightest" staff to cooperative ventures. It was also recommended that industry include representatives from the various operating units of the organization -- from research to design to production to marketing -- in research partnerships.

State Government Support for Cooperative Research. It was also recommended that government, particularly state government, plays an important role in encouraging industry/university cooperation. As discussed earlier, the participants reacted positively to current state efforts to support research and development. In addition to supporting joint industry/university research projects, approximately half of the business respondents and two-thirds of the university respondents gave research matching grants a high rating.

One area in which the survey respondents disagreed with the meeting participants concerned state efforts to target particular industries. Since one strategy which states are pursuing is to target certain technologies, the survey asked the respondents' opinion on targeted strategies. In the survey, both industry and university officials rejected such a strategy.

Some respondents indicated that they were distrustful of the ability of either state or federal government officials to implement effectively a targeting strategy. They suspected the decision to target would be politically-determined rather than economically sound. Another cautioned that "there is a lot of herd behavior and, frequently, important breakthroughs come from areas that are unpopular at a particular time." Meeting participants largely took the position that targeting, if it were to be done, should be done at the state, not the federal, level. Some participants favored state targeting, arguing that states have the ability to identify technological niches of importance to both their own and regional economies.

The meeting participants highlighted two aspects of state initiatives that they found very promising. The first is that the states have developed integrated strategies for pursuing economic competitiveness, and the second is the experimentation occurring at the state level.

With regard to the former, a university official referred to the imaginative leadership taken by the nation's Governors in building a strategy for job creation. "This strategy focuses on a state-based program emphasizing an attractive business climate, education reform, and encouragement of new technological capabilities wherever they can be nourished."

He added: "I think it is a tremendously important contribution state Governors have made and I think this is something that federal officials need to look at very hard. Since the federal government has not, in my opinion, integrated its education strategy, its technology strategy, and its business encouragement strategy into nearly as coherent a strategy as the state of New Jersey, the state of Massachusetts and several others." He recommends a closer relationship between federal agencies that support science and technology and the states that are building meaningful strategies.

The issue of federal/state cooperation was raised at each of the meetings. The participants were generally supportive of new federal initiatives of the National Science Foundation and other federal agencies to encourage multidisciplinary, cooperative research, specifically, the Engineering Research Centers, University/Industry Cooperative Research Centers and the newly-proposed Basic Science and Technology Centers of the National Science Foundation, and the Department of Defense's University Research Initiative.

The chairman of a state commission on science and technology argued, however, that the impetus for cooperative research and development must remain with the states. "We in the states are close to our people, close to our industries, and certainly close to our higher education institutions." He added that the states need help in forging research and development partnerships and asked that the federal government, particularly the National Science Foundation, work with the states in strengthening these new partnerships.

Assessing Progress to Date. Finally, a few words of caution were raised regarding the danger of excessive expectations for cooperative research ventures. The Dean of Engineering at a major university stated: "It is going to take some time for this experiment to mature, and the expectations, particularly at the state level, are for instant success... Its going to take at least a decade to know whether bright young people are coming into the field of manufacturing and technology for the civilian market, before we have a real sense of change."

Erich Bloch, Director of the National Science Foundation, defined success somewhat differently.

> "I would define success as follows: if universities change in two ways. First of all, by developing cooperative relationships with industry, and also between their own departments and disciplines. The second measure is the contribution made by science and technology and engineering centers to the educational process. And I would say if this can be achieved, then I would call this Great Experiment a success."

The issue of experimentation was raised again and again by meeting participants. "The thing about the state governments, I think that is exciting, is that no one assumes he has the answer, and everyone is trying experiments. A lot of them are going to fail, but many of them are going to succeed." said the Vice-President for Research of a major midwestern corporation. The meeting participants also felt that the fact that these efforts are experimental means there is need to measure the outcomes of these efforts and assess their effectiveness.

CREATING AN INNOVATIVE ENVIRONMENT: GETTING IDEAS TO THE MARKETPLACE

A strong research and development base, in and of itself, is not sufficient to maintain U.S. competitiveness. There is an additional need to ensure that the knowledge and technology developed are actually used. In fact, this is the area in which U.S. performance is viewed as weaker than many of our major competitors. For example, the videocassette recorder was invented in the United States in 1956; today not one VCR is produced in the United States, and two Japanese firms, Sony and Matsushita control 90 percent of the U.S. market. There is also concern that American manufacturers have been slow to automate. Indicative of the growing lapse in commercialization, in 1986, for the first time, the United States ran a trade deficit of high-technology products.

Researchers asked the study participants to take a broad look at what they regard as some of the most significant barriers to innovation. Business, university, and state officials responded to this request by first describing the barriers they consider important to the nation, and then focusing on barriers that seem to have particular relevance to their region.

Transfer of Technology

The survey respondents gave technology transfer a low ranking in terms of its importance to U.S. competitiveness in comparison with human resources, research and development resources, and federal fiscal, trade, and regulatory policies. While 62 percent of the business respondents ranked human resources as one of the top two issues affecting competitiveness and 40 percent ranked research and development resources as critical factors, only 12 percent ranked technology transfer as one of the top two issues affecting U.S. competitiveness.

The university respondents also gave human resources and research and development resources the top rankings out of the six topic areas. State officials similarly ranked human resources as the most significant factor affecting competitiveness, but also ranked U.S. trade and fiscal policy higher than technology transfer.

These results are somewhat surprising given the commonly accepted wisdom that it is in the area of commercialization, i.e., moving products to market, where the United States falls behind its major competitors. Several meeting participants indicated that they disagreed with the survey findings on this point, indicating that they felt technology transfer was of crucial importance to the nation's competitiveness.

One explanation for the low ranking given to technology transfer may lie in the definition of the term. While technology transfer may be used in a very general sense to refer to the entire process by which a product or service goes from the idea stage to commercial application, the term can be defined more narrowly to refer to the transfer of information from researchers to users. One would expect to receive different responses from the survey respondents based on their interpretation of the term. It should also be kept in mind that the business responses to the survey came mainly from vice-presidents for research and development, individuals likely to be more concerned about research and development resources and their access to skilled engineers and scientists than about finding out about new processes that might be applied to production processes.

Several of the meeting participants made a further distinction in terminology, saying that U.S. industry has not had a problem with commercialization, i.e., bringing a product to market, rather our competitive problems have involved production and marketing -- being able to produce a high quality product at a competitive price.

The executive of a major midwestern company commented:

"The nature of the problem clearly has to do with our implementation. Where we have fallen down is in the quality of implementation, the cost of implementation, and the approach to continuous improvement as our competitors have relentlessly moved forward."

With regard to specific barriers to technology transfer, the survey respondents were asked to rank four issues. Their responses are shown in Tables 5 and 6. More than half of the businesses surveyed believe that the time lag in the commercialization of new technology by industry is an issue that puts the United States at a competitive disadvantage in world markets. When one looks at the variance between the impact on a particular firm, university, or state and the impact on the entire economy, we find no differences in ranking, although in all categories the respondents believed each issue had a greater impact on the national economy than on their individual company, university, or state. But while 22 percent of the respondents from the business sector said that property rights and patent reform are of critical importance to their firms, 35 percent thought that it was of critical significance to the U.S. economy.

State and university officials feel much more strongly about the lack of access to federally-sponsored research and the effect that this issue has on competitiveness than business leaders. While less than one-third of the businesses believe that access to federally-sponsored research is having a significant impact on competitiveness, 40 percent of the universities and 50 percent of the state officials believe this is affecting U.S. competitiveness.

In addition, nearly half of the state respondents rate clarification of policy on intellectual property rights and patent reform as a critical issue affecting U.S. competitiveness. Less than one-tenth of the state and company officials, and very few universities, are critically affected by foreign governments' restrictions over the transfer of technology developed by U.S. subsidiaries in those countries.

Barriers to Commercialization. Respondents from all three sectors faulted the business community for lack of patience, for thinking of the next quarter's profits rather than the potential payoff from long-term investments in product development. Short-term responsibility to shareholders was acknowledged, and how that is often at the expense of product development which can occur only over the long-term. During the regional meetings, a number of the participants shared with the audiences personal or corporate experiences reflecting on markets lost to foreign producers -- markets for products in which America invented the technology.

Table 5

Barriers to Technology Transfer
Percentage of Respondents Rating Issue as Critical to the Competitiveness of the U.S. Economy

	Business	University	State
Excess time lag in commercialization of technology by:			
A. industry	52%	42%	42%
B. universities	27	35	35
Lack of clarification of policy on intellectual property rights and patent reform	35	26	49
Lack of access to federally-sponsored research results by.			
A. industry	27	42	51
B. universities	29	42	51
Foreign government prohibitions restricting transfer of technology from their territories by U.S. firms	18	23	30

Table 6

Barriers to Technology Transfer
Percentage of Respondents Rating Issue as Critical to the Competitiveness of Their Company, University, or State

	Business	University	State
Excess time lag in commercialization of technology by:			
A. industry	37 %	12 %	40 %
B. universities	14	14	33
Lack of clarification of policy on intellectual property rights and patent reform	21	15	42
Lack of access to federally-sponsored research results by:			
A. industry	18	19	40
B. universities	18	33	37
Foreign government prohibitions restricting transfer of technology from their territories by U.S. firms	9	4	10

In discussing the reasons for American industry's poor performance, the respondents and meeting participants placed some of the blame on management. In some instances it appeared that corporate bureaucracy had gotten in the way of rapid commercialization of American-bred technology. Business' lack of long-term goals and vision has hindered the commercialization of U.S. technology, commented several corporate respondents.

Many of the state officials responding to the survey echoed this concern. When asked to list the three most significant barriers to innovation in their state, responses included: "industrial reluctance to abandon traditional objectives for manufacturing", "lack of awareness of technological threats to their future" on the part of industry, and "attitude of private industry toward need for long-term innovation".

A number of company representatives decried the lack of intellectual property rights protection among foreign competitors and claimed that their secrecy and unwillingness to test market certain innovations was based on their reluctance to expose product prototypes to foreign firms that would pirate such breakthroughs.

Small Company Concerns. Some respondents suggested that in order to address these problems, we should look to small business as a source of innovation. It was suggested that small businesses are more likely to introduce new products in the market and to adopt new technological processes. One reason given for this is that "entrepreneurs are staking their careers, their lives, literally their livelihood to develop a technology. They have a vision."

Respondents and meeting participants from small companies also pointed out many of the barriers faced by new technology-based firms. First and foremost among them is lack of venture capital. Several speakers referred to the desire on the part of venture capitalists to want their money back quickly.

Another panelist pointed out:

> "The problem with venture capitalist money is that it is very expensive. You're talking about royalties of 6, 7, 8, or 9 percent. Normally your profit is 6, 7, 8, or 9 percent. So when your're paying a venture capitalist, the company starts teetering."

A program reported to be particularly effective in providing "seed" capital for new businesses is the federal Small Business Innovation Research Program (SBIR). The program, established in 1982 by the Small Business Innovation Development Act, requires that each federal agency with an external research and development budget exceeding $100 million spend a specified percentage (up to 1.25 percent) of such budget via a special program targeted to small firms.

But providing capital for new products and new businesses, while necessary, may not be sufficient. In addition, many inventors or entrepreneurs need assistance in a variety of areas from developing a business plan to managing and training a workforce.

The director of a state-supported product development fund described his agency's experience as follows:

One of the things that we have learned is that, in terms of commercialization, it is not sufficient with most companies for us to provide only the funding for product development. There are two additional functions that have to be provided. One is assistance in either obtaining or supplying the money necessary to enter the marketplace. The second is perhaps more important -- and a lot harder to define -- and that's "hand holding." This is important for companies that are short on management skills in one area or another. We believe that if our investment is to stand the greatest chance of success, we're going to need to provide support services."

Several small business owners participating in the meetings identified their need for technical support services as follows:

"We need capital equipment, part-time expertise, and the resources to train people. In any kind of a high-technology business, there is no way you can do it all yourself as a small business."

Another entrepreneur proposed: "Providing funding to bring faculty out to our companies and have them work with us. We cannot support them ourselves."

Additional suggestions offered for improving commercialization include:

- Develop more accurate indicators of technology transfer so that U.S. strategists have a better grasp of the dimensions of this problem.
- Increase the interaction between technologists at primary manufacturing firms and those in supplier firms.
- Develop a cadre of technology transfer agents or mechanisms that will permit entrepreneurs to acquire and commercialize technology discoveries unused by either major laboratories or university research centers.
- Provide specialized advice and technical support for small firms seeking to commercialize leading-edge technologies.

The meeting participants regard commercialization as one of the leading factors in keeping America competitive. They are dissatisfied with the mechanisms now available and are searching for improvements and replacements.

State Programs That Bridge the Gap

State governments have developed a range of programs designed to speed the application of new technology to the marketplace. These include both financial and non-financial assistance for entrepreneurs and small business owners and efforts to provide these same entrepreneurs and business owners with access to research resources, particularly at universities. The survey respondents were given a list of state initiatives and asked to indicate first, their level of interest in each program, second, whether they had used the program, and finally, their evaluation of it.

The programs designed to promote technology transfer include:

- patent assistance,

- technical consulting services, including assistance in preparing feasibility studies, product testing, and prototype development,

- technical extension services, modeled after the agricultural extension service (these services usually employ field staff who call on businesses providing technical advice and problem solving to individual businesses),

- libraries and data banks,

- technical data services, often computerized data bases that list ongoing research within the state as well as information on researchers, venture opportunities, and patent applications,

- state liaison to provide access to federal laboratories and research facilities,

- research and science parks,

- start-up, venture, or seed capital,

- funds for product development, testing, or prototype development,

- investment capital for facilities, machinery, and equipment, and

- incubator facilities for start-up firms, facilities that provide low-rent office and lab space along with technical and management assistance.

In terms of interest in the programs, the industry respondents gave the highest ranking to product development funds, with 42 percent indicating a high level of interest followed by libraries and databases with 35 percent and investment capital ... 32 percent. The businesses expressed little interest in patent assista[illegible] technical extension services, and site location assistance services. [illegible]ables 7 and 8.

The university respondents, in general, indicate greater interest in the state initiatives than do business respondents. Sixty-nine percent of the university respondents indicate a strong interest in investment capital, 64 percent in libraries and databases, 56 percent in technical data services, and 54 percent in venture or seed capital. As in the case of business respondents, patent assistance and technical extension services ranked poorly in terms of interest for university leaders.

The state officials surveyed were asked to indicate how critical they felt the need for each type of program to be. By and large, their rankings of need were much higher than the businesses' indication of interest. Almost three-fourths of the state respondents believe there is a strong need for both venture capital programs and technology extension services. Other programs that received high rankings by the state officials include: science parks, investment capital, need to access federal labs, site location assistance and incubators. Once again, the program perceived as least important, although 42 percent of the state respondents felt it was needed, was patent assistance.

Table 7

Financial Assistance Programs
Percentage of Respondents Indicating a High Degree of Interest in, or Need for, Program

	Business	University	State
Start-up, venture, or seed capital	27%	54%	73%
Funds for product development, testing, prototypes, etc.	42	42	59
Investment capital for facilities, machinery, and equipment	32	69	66

Table 8

Non-Financial Assistance Programs
Percentage of Respondents Indicating a High Degree of Interest in, or Need for, Program

	Business	University	State
State libraries and data bases	35%	64%	59%
Technical data services (on faculty research, venture opportunities, etc.)	33	56	46
Research and science parks	27	46	67
Pooling of regional research resources	26	48	54
Technical consulting services (feasibility studies, product testing prototype development)	25	38	51
"Incubator" facilities for start-up firms (low rent office/lab space)	24	53	59
State liaison to provide access to federal laboratory and research facilities	21	50	65
Site location assistance for R&D facilities	17	32	62
Technical extension services (state field staff who provide technical advice and support	13	28	72
State patent and licensing assistance services	11	11	42

This differential in the perceptions of the state, industry, and university respondents, in terms of the need for various programs, might be explained by the fact that the majority of these programs are targeted not toward the larger well-established firms who comprise the majority of the survey respondents, but toward new, small firms, and entrepreneurs.

The majority of state programs are designed to serve the technological innovator or entrepreneur and very small businesses, often with fewer than ten employees. To assess the effectiveness of these services, surveys were sent to 700 small firms in six selected states. An insufficient number of responses were received from this sample to provide significant results.

The survey data for all firms within the six selected states were broken down by size of firm using less than 500 employees as one category and 500 or more employees as the other. The data for firms with less than 500 employees shows generally a higher level of interest in the state programs. See Tables 9 and 10.

The respondents were also asked whether they were aware of the various state programs, whether they had used them and their assessment of the programs. Although thirteen states reported operating patent assistance programs, only 9 percent of the industry respondents were aware of such programs and less than one percent had used them.

Technical consulting services are provided in seventeen states. Less than one-third of the businesses surveyed were aware of these programs. Although they received a relatively low evaluation from both industry and universities, only 19 percent of the businesses had used them, and for the most part, the size of the firm responding to the survey indicates that they would not need such services having access to on-staff technical expertise. The same probably holds true regarding the use of technology extension services.

Technical extension services now operate in twenty-five states. While 26 percent of the businesses were aware of the program, only 9 percent had used it. Thirty-five percent of the businesses gave it a low ranking while 19 percent ranked it highly. On the other hand, 73 percent of the state officials ranked technical extension services as highly effective. Once again, these services are designed to assist small and medium-sized companies and are less likely to be of use to large corporations.

Less than half of the business and slightly more than half of the university respondents were aware of libraries and databases and had used them. Thirty-six percent of the industry respondents and 65 percent of the university respondents rated them highly in terms of effectiveness.

Although fourteen states reported programs to increase access to federal laboratories, only 13 percent of the business respondents and 23 percent of the university respondents were aware of these programs. Sixty-six percent of the university respondents ranked state venture capital programs as effective, as did 37 percent of the business and 42 percent of the state officials. Only 8 percent of the businesses had used state venture capital programs. The state officials ranked product development funds as slightly more effective than venture capital funds, although 30 percent of the businesses ranked product development funds as very low in effectiveness.

Table 9

Financial Assistance Programs
Percentage of Businesses Indicating a High Degree of
Interest in Program By Size of Firm

	Less than 500 employees	500 or more employees
Start-up, venture, or seed capital	40%	26%
Funds for product development, testing, prototypes, etc.	54	31
Investment capital for facilities, machinery, and equipment	54	30

Table 10

Non-Financial Assistance Programs
Percentage of Businesses Indicating a High Degree of Interest in Program By Size of Firm

	Less than 500 employees	500 or more employees
State libraries and data bases	48%	32%
Technical data services (on faculty research, venture opportunities, etc.)	36	30
Research and science parks	29	28
Pooling of regional research resources	14	26
Technical consulting services (feasibility studies, product testing prototype development)	28	25
"Incubator" facilities for start-up firms (low rent office/lab space)	38	22
State liaison to provide access to federal laboratory and research facilities	16	23
Site location assistance for R&D facilities	13	18
Technical extension services (state field staff who provide technical advice and support	24	12
State patent and licensing assistance services	20	11

Site location assistance, science parks, and incubators were generally believed to be more effective by state officials than by either university or business officials. Once again, this can probably be explained by size of firm. The data also seem to indicate, however, that additional outreach is needed to ensure that the business and university people are aware of the services available to them.

NATIONAL POLICY ISSUES

While the survey participants concentrated on human resources, education, R&D investments, and state assistance programs, they also had an opportunity to comment on and evaluate a variety of economic and regulatory policies which are also said to impact U.S. international competitiveness.

Regulatory Policies

There were three principal regulatory issues that seem to most concern respondents. These, and their relative importance are shown in Tables 11 and 12.

A majority of those surveyed for each of the issues described above, believe that government regulation has only slight effect on rese ch and development and education in their organization. Many, however, when posed the larger question of whether the U.S. regulatory climate has an impact on competitiveness, respond in the affirmative. Less than one-third of the business leaders find any of the three issues to be of critical strategic importance to research and development in their organizations.

Individual respondents within selected industries or universities, may view this situation differently because of the impact that regulation may have on their particular organizations. This is also true when respondents consider the effect that certain regulatory activities might have on the economy at large. For example, when university respondents considered the latter impact regarding the regulation of new technology, nearly half believe this issue to be of critical importance. But, overall, regulation is not regarded as an insurmountable barrier to competitiveness.

The Impact of U.S. Trade Policy and Practice. The survey participants were well aware, particularly in light of the debate now going on in the Congress, that there are numerous trade policies and strategies, as practiced by both the U.S. and foreign governments, which can affect the competitive capability of U.S. business. After conferring with trade specialists, the authors identified four issues thought to be of primary importance. These issues and their importance, are shown in the Tables 13 and 14.

While only a minority of the business leaders questioned view these issues as being of critical importance to their individual businesses, on average, more than half of them believe all of these issues to be of critical importance for the overall economy. For example, only 17 percent are critically affected by the export control of U.S.-developed technology, but more than twice that number believe that such policies critically impact the ability of the United States to compete with its trading partners. And, while slightly more than one-quarter say that, for their firms, foreign trade barriers are of critical importance, nearly two-thirds believe that such practices are of critical importance to the United States.

As can be seen from the above table, university officials -- perhaps because they deal primarily in data -- regard restrictions of transnational data flow with more concern than do the business executives surveyed. Looking at the economy in general, university executives also believe that removing protectionist measures enacted by other countries is a key to improving our nation's competitive abilities.

Table 11

Regulatory Issues
Percentage of Respondents Rating Issue as Critical to the Competititiveness of the U.S. Economy

Issue	Business	University	State
Impact of regulatory reform on operations	29%	35%	30%
Regulation of new technology, e.g., biotechnology, etc.	39	41	40
Federal cost/benefit analysis for new technology	16	23	8

Table 12

Regulatory Issues
Percentage of Respondents Rating Issue as Critical to the Competititiveness of Their Company, University, or State

Issue	Business	University	State
Impact of regulatory reform on operations	19%	27%	39%
Regulation of new technology, e.g., biotechnology, etc.	18	12	24
Federal cost/benefit analysis for new technology	10	8	5

Table 13

Key Trade Policies
Percentage of Respondents Rating Issue as Critical to the Competitiveness of the U.S. Economy

Issue	Business	University	State
Targeting, by foreign governments, of certain technologies	67%	56%	60%
Trade Protection, by other countries, of certain domestic industries	60	53	65
Export control of U.S. technology and products	40	51	46
Control of transnational data flow	29	43	43

Table 14

Key Trade Policies
Percentage of Respondents Rating Issue as Critical to the Competitiveness of Their Company, University, or State

Issue	Business	University	State
Targeting, by foreign governments, of certain technologies	29%	7%	32%
Trade Protection, by other countries, of certain domestic industries	27	4	52
Export control of U.S. technology and products	17	22	33
Control of transnational data flow	12	15	26

The state government officials questioned tend to regard trade policy as much more important to both their state's economic well being, as well as to the nation's, than do their counterparts in the private sector.

Fiscal and Monetary Policy. Three issues were deemed to be of critical importance from a fiscal or monetary policy standpoint, with significant variation as to how these issues were ranked in terms of their impact on the firms vs. the economy at large. In Tables 15 and 16 we can see how business leaders and university officials believe the issues to impact the nation's economy.

Nearly two-thirds of the business leaders queried say that the federal budget leads the list of fiscal or monetary issues restricting our ability to compete with European or Asian competitors. Fewer than one in ten rank this issue of slight or no importance. And nearly half believe that the way the government treats R&D investments has a critically negative effect on our ability to remain competitive. Their views are echoed by university officials, with nearly three-quarters of them believing that the federal budget deficit is of major importance to competitiveness. State government officials are even more vehement in insisting that the federal budget deficit is holding back the U.S. drive to remain internationally competitive. State government officials consistently rank this as the most important fiscal or monetary policy issue.

The Issue of Targeting. Certain of our international competitors, Japan in particular, are said to be engaged in a competitive strategy referred to as "targeting." A few years back the same type of activity, or a more generalized variation of it, was referred to as "industrial planning," "industrial policy," etc. In essence, the concept involves the conscious decision by business and government authorities, acting in concert, to focus on the development of certain technologies or industries. This focusing can--and has--involved the granting of government subsidies to such industries or technologies, the erection of tariff or nontariff trade barriers to protect domestic producers, the shifting of technical resources and financial support to the chosen industries, and a variety of other steps designed to protect the chosen industries' place in the sun.

Nearly any discussion of international competitiveness invariably touches on this issue and this study project was no exception. The Conference Board has conducted previous studies which have dealt with various trade and protectionism matters and has had a chance to monitor business and government sentiment on this issue. This study finds growing support for a limited use of the targeting strategy. While business leaders--and a majority of university officials--continue to regard economic planning as an anathema and voice opposition to any government-planned economic activity, they do show growing support for the concept that certain states might adopt a development strategy based on targeting principles.

The key difference lies in the recognition that certain states and regions already have natural resource bases or certain technological characteristics and that it is reasonable to build on these existing assets. In California and Massachusetts, for example, as well as Texas and several other states, there is already a strong electronics industry. In Michigan and the Midwest there already have been significant gains in CAD-CAM and robotics applied to the manufacturing process. In New Jersey there is a significant amount of

Table 15

Fiscal and Monetary Issues
Percentage of Respondents Rating Issue as Critical to the Competitiveness of the U.S. Economy

Issue	Business	University	State
Impact on federal budget deficit	58%	71%	78%
Tax policy on treatment of R&D investments	49	51	65
The value of U.S. currency in markets	45	51	43

Table .o

Fiscal and Monetary Issues
Percentage of Respondents Rating Issue as Critical to the Competitiveness of Their Company, University, or State

Issue	Business	University	State
Impact on federal budget deficit	28%	39%	57%
Tax policy on treatment of R&D investments	31	16	41
The value of U.S. currency in markets	31	6	30

research and manufacturing skills in ceramics and sophisticated construction materials as well as communications technology.

These states, their industries and universities, are making a concentrated effort, through targeted R&D efforts, to build on these bases. At the same time, other states are coming to realize that it makes little sense to attempt to duplicate their sister states' R&D targeting and are, instead, looking for niches where they have a unique resource or technology advantage and directing their R&D investments to such sectors.

CONCLUSION

This study was designed to address a variety of issues. First, was to determine the importance of research and education to the economic competitiveness of the United States. Second was to determine which of the following factors are believed to have the greatest impact on U.S. competitiveness -- human resources, research and development investments, technology transfer, or federal fiscal, monetary, regulatory and trade policy. Third was to canvass the research community to determine what changes need to be made to strengthen and improve the nation's research and education system. A final issue was to compare the perceptions of three different communities -- the business sector, the academic community, and state governments -- with regard to research and education policies and to identify how the roles of each of these organizations is changing to meet the competitive challenge of today's economy.

The analysis of the survey data and the discussions which occurred at the regional meetings showed that there is a great deal of similarity in the perceptions of these three groups. The industry, university and government leaders participating in the study agreed that science and engineering research and education have in the past, and will continue in the future, to play a crucial role in determining U.S. competitiveness. They further agreed that for the most part, the United States has a healthy and vibrant research and education system. Yet to maintain its competitive position and retain its technological leadership in the face of increased investment in research and education by our foreign competitors, the United States must continue to increase its investment in these areas.

With regard to the most important factor affecting the nation's future competitiveness, all three groups viewed education as the key. Furthermore, there was general agreement that the area of education of greatest concern is mathematics and science education at the K - 12 level. While efforts to improve primary and secondary mathematics and science education rests primarily with state government, the study participants suggested that both universities and the business community have a role to play in improving K - 12 education.

At the university level, business and state officials joined their university counterparts in calling for increased investment in state-of-the-art facilities and equipment. Business officials, as might be expected, were greatly concerned with developing and maintaining an adequate supply of science, engineering and technical personnel. This concern was shared by university and state officials. While the three groups agreed that there is a need for high level technical training, continuing education and job retraining, opinion was divided with regard to whether industry, community colleges or universities should have responsibility for providing continuing education and training.

With regard to research and development investments, all three groups believe that the U.S. must increase its investment in civilian basic research, if the the U.S. is to remain competitive. In addition, there is a belief that the nature of research and development is changing, i.e. it is becoming more complex, more capital-intensive, increasingly multi-disciplinary, and dependent on sophisticated instrumentation and computers. One response to these changes has been the creation of new institutional relationships between businesses and universities. The study indicated that while today's new government/university/industry partnerships are generally well received, these relationships are evolving and will require additional adjustments on the part of both business and universities.

It was generally recognized that state governments can, and are, playing a catalytic role in fostering cooperative research, but while state officials wholeheartedly support cooperative research as an avenue to improving U.S. competitiveness, less than half of the business respondents felt that cooperative research will be critical to the nation's competitive position. University officials, meanwhile, expressed some reservations about the demands being placed on the university system as partners in cooperative research ventures while being generally supportive of the changes occurring in university/industry relationships. It appears clear that while progress has been made, much additional work remains before government/industry/university roles are sorted out.

A surprising finding of the study is the lack of concern by business executives with the issue of technology transfer. Discussion at the regional meetings indicates that part of the reason for this is confusion with the term "technology transfer". There was concern expressed regarding the excessive time lag in the commercialization and adoption of new technology yet few suggestions were made for ways to address this issue. It appeared clear that impediments to commercializations is an area requiring more in-depth study.

In addition to determining the views of business, state government, and university officials on research, education, and competitiveness, the study raised a number of issues that merit further consideration. First, what actions should be taken to improve science and mathematics at the primary and secondary school levels? Second, demographic changes and a decline in the number of American students pursuing science and engineering degrees will necessitate increased involvement of women and minorities in science and engineering. How is this to be achieved? Third, how can long time lags in the commercialization process be reduced? Fourth, university/industry partnerships should be evaluated and their performance tracked over time. By what criteria do we judge their performance and their contribution to the generation and transfer of knowledge?

Lastly, future partnerships require redefinition. What is the relationship between state initiatives and federal efforts regarding research and development? Are state/federal partnerships needed, and if so, how should they be structured? How would a restructuring affect the private sector and the academic community? These are questions that should be addressed if the United States is to meet the growing economic challenge.

The Conference Board

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APPENDIX I: Survey Instrument for Industry*

The Role of Research and Education in Economic Competitiveness

The Conference Board, with support from the National Science Foundation, has joined with the National Governors' Association in a cooperative project designed to obtain the views of key industry executives, state policymakers and key university officials on issues of science and technology and their impact on economic and technological competitiveness. This questionnaire, along with discussion forums to be held next spring, will provide valuable data to science-policy architects in the executive branch, Congress, industry and state governments.

This study provides you with an opportunity to present your views on which issues of science policy are most significant to your firm, which policies and practices most affect the nation's international competitiveness, and which ways government can best work with the private sector and academia in improving the U.S research and development base.

Your replies will be held in strict confidence by The Conference Board and there will be no attributions to your firm without your explicit permission.

*****

10-11

Name________________________ Title________________________ 12-13

Company____

Address____

City____________________ State________ 14-15 Zip________ Tel. (   )____________

Annual Sales________________ 16-23 Total Number of Employees ________________ 24-29

Principal Products or Services____ 30-33

*Comparable survey forms were sent to state and university officials.

The Role of Research and Education in Economic Competitiveness

The questions that follow deal with six major categories of economic/managerial policy and practices which impact America's economic competitiveness. These are issues which are believed to be of interest to, and which will affect, both the public and the private sector. This portion of the questionnaire seeks to evaluate their importance, in your professional judgment, to your firm and to society at large. The topics are divided according to what impact they will have on your company and on society at large.

1. Educational and Human Resource Policies and Practices

The nation's international competitiveness can no doubt be impacted by America's educational resources and by the policies of both the private and public sector in the support and development of these resources. The following questions focus on some of the issues surrounding these topics.

Issues Title/Description	Strategic Impact on Your Business				Strategic Impact on U.S. Econom			
	Critical	*Moderate*	*Slight*	*None*	*Critical*	*Moderate*	*Sligh*	*ne*
Developing and maintaining adequate supply of science, engineering, and technical personnel.	34-1 ☐	2 ☐	3 ☐	4 ☐	35-1 ☐	2 ☐	3 ☐	4 ☐
Preparation of elementary and secondary students in science and mathematics.	36-1 ☐	2 ☐	3 ☐	4 ☐	37-1 ☐	2 ☐	3 ☐	4 ☐
Supply and quality of science teachers at all levels.	38-1 ☐	2 ☐	3 ☐	4 ☐	39-1 ☐	2 ☐	3 ☐	4 ☐
Developing public understanding of science & engineering.	40-1 ☐	2 ☐	3 ☐	4 ☐	41-1 ☐	2 ☐	3 ☐	4 ☐
Cost-benefits of obtaining a science or engineering education vs. other graduate training.	42-1 ☐	2 ☐	3 ☐	4 ☐	43-1 ☐	2 ☐	3 ☐	4 ☐
Preparation of undergraduate students in science and engineering curriculum.	44-1 ☐	2 ☐	3 ☐	4 ☐	45-1 ☐	2 ☐	3 ☐	4 ☐
Availability and value of continuing education programs.	46-1 ☐	2 ☐	3 ☐	4 ☐	47-1 ☐	2 ☐	3 ☐	4 ☐
Increased reliance of U.S. industry on foreign student graduates of U.S. universities.	48-1 ☐	2 ☐	3 ☐	4 ☐	49-1 ☐	2 ☐	3 ☐	4 ☐
Other educational issues____ ________________	-1 ☐	2 ☐	3 ☐	4 ☐	51-1 ☐	2 ☐	3 ☐	4 ☐

2. Research and Development Resources

Research and development resources must not only be adequate to the task of maintaining competitiveness but must also be distributed in such a manner that industry and universities can take maximum advantage of them. This section of the questionnaire looks at some of the issues pertaining to that distribution.

Issues Title/Description	Strategic Impact on Your Business				Strategic Impact on U.S. Economy			
	Critical	*Moderate*	*Slight*	*None*	*Critical*	*Moderate*	*Slight*	*None*
Concentration of research and development resources in the defense sector.	52-1 ☐	2 ☐	3 ☐	4 ☐	53-1 ☐	2 ☐	3 ☐	4 ☐
Access to state-of-the-art R&D equipment and facilities								
A. by industry	54-1 ☐	2 ☐	3 ☐	4 ☐	55-1 ☐	2 ☐	3 ☐	4 ☐
B. by universities	56-1 ☐	2 ☐	3 ☐	4 ☐	57-1 ☐	2 ☐	3 ☐	4 ☐
Increased support for civilian basic research as performed								
A. by industry	58-1 ☐	2 ☐	3 ☐	4 ☐	59-1 ☐	2 ☐	3 ☐	4 ☐
B. by universities	60-1 ☐	2 ☐	3 ☐	4 ☐	61-1 ☐	2 ☐	3 ☐	4 ☐
Significance of increasing industry support for university-based research	62-1 ☐	2 ☐	3 ☐	4 ☐	63-1 ☐	2 ☐	3 ☐	4 ☐
Importance of cooperative research:								
A. among industries	64-1 ☐	2 ☐	3 ☐	4 ☐	65-1 ☐	2 ☐	3 ☐	4 ☐
B. among industries and universities	66-1 ☐	2 ☐	3 ☐	4 ☐	67-1 ☐	2 ☐	3 ☐	4 ☐
Other R&D issues__________ __________	68-1 ☐	2 ☐	3 ☐	4 ☐	69-1 ☐	2 ☐	3 ☐	4 ☐

3. Transfer of Technology

A variety of policies and practices affect how successfully, and within what time span, innovative ideas and products move from research and development to commercialization. Public policies, as executed both by the U.S. and foreign governments may also influence the implementation of such technology. The questions below focus on some of these issues.

Issues Title/Description	Strategic Impact on Your Business				Strategic Impact on U.S. Economy			
	Critical	*Moderate*	*Slight*	*None*	*Critical*	*Moderate*	*Slight*	*None*
Clarification of policy on intellectual property rights and patent reform.	10-1 ☐	2 ☐	3 ☐	4 ☐	11-1 ☐	2 ☐	3 ☐	4 ☐
Foreign government prohibitions restricting transfer of technology from their territories by U.S. firms.	12-1 ☐	2 ☐	3 ☐	4 ☐	13-1 ☐	2 ☐	3 ☐	4 ☐
Time lag in commercialization of technology by:								
A. industry	14-1 ☐	2 ☐	3 ☐	4 ☐	15-1 ☐	2 ☐	3 ☐	4 ☐
B. universities	16-1 ☐	2 ☐	3 ☐	4 ☐	17-1 ☐	2 ☐	3 ☐	4 ☐
Access to federally-sponsored research results by:								
A. industry	18-1 ☐	2 ☐	3 ☐	4 ☐	19-1 ☐	2 ☐	3 ☐	4 ☐
B. universities	20-1 ☐	2 ☐	3 ☐	4 ☐	21-1 ☐	2 ☐	3 ☐	4 ☐
Other __________ __________	22-1 ☐	2 ☐	3 ☐	4 ☐	23-1 ☐	2 ☐	3 ☐	4 ☐

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4. Federal Regulatory Policy

Obviously, the actions of the U.S. government from a regulatory action standpoint, can impact firms, and universities. These questions concentrate on some of the more frequently cited issues in this area.

Issues Title/Description	Strategic Impact on Your Business				Strategic Impact on U.S. Economy			
	Critical	*Moderate*	*Slight*	*None*	*Critical*	*Moderate*	*Slight*	*None*
Regulation of new technology e.g. biotechnology, etc.	24-1 ☐	2 ☐	3 ☐	4 ☐	25-1 ☐	2 ☐	3 ☐	4 ☐
Federal cost-benefit analysis requirements for technology.	26-1 ☐	2 ☐	3 ☐	4 ☐	27-1 ☐	2 ☐	3 ☐	4 ☐
Impact of regulatory reform on university and business research operations.	28-1 ☐	2 ☐	3 ☐	4 ☐	29-1 ☐	2 ☐	3 ☐	4 ☐
Other ______	30-1 ☐	2 ☐	3 ☐	4 ☐	31-1 ☐	2 ☐	3 ☐	4 ☐

5. U.S. Trade Policy and Practice

There are numerous trade policies and practices, as established by the U.S. government, or by foreign governments, that can affect the competitiveness of U.S. business. Our interest focuses in particular, on those that have a long-term technological component. From the list cited below please indicate whether you believe these issues will have strategic importance to your company and to the U.S. economy as a whole.

Issues Title/Description	Strategic Impact on Your Business				Strategic Impact on U.S. Economy			
	Critical	*Moderate*	*Slight*	*None*	*Critical*	*Moderate*	*Slight*	*None*
Export control of U.S. technology and products.	32-1 ☐	2 ☐	3 ☐	4 ☐	33-1 ☐	2 ☐	3 ☐	4 ☐
Control or restriction of transnational data flow.	34-1 ☐	2 ☐	3 ☐	4 ☐	35-1 ☐	2 ☐	3 ☐	4 ☐
Protection, by other countries, of key industries.	36-1 ☐	2 ☐	3 ☐	4 ☐	37-1 ☐	2 ☐	3 ☐	4 ☐
Targeting, by foreign governments, of certain technologies.	38-1 ☐	2 ☐	3 ☐	4 ☐	39-1 ☐	2 ☐	3 ☐	4 ☐
Other trade policies or practices. ______	40-1 ☐	2 ☐	3 ☐	4 ☐	41-1 ☐	2 ☐	3 ☐	4 ☐

6. Fiscal and Monetary Policy

The actions of the U.S. government, in establishing a national fiscal and monetary policy, can impact the private sector's international competitiveness. This section seeks your views on a few key elements of these federal policies.

Issues Title/Description	Strategic Impact on Your Business				Strategic Impact on U.S. Economy			
	Critical	*Moderate*	*Slight*	*None*	*Critical*	*Moderate*	*Slight*	*None*
Tax policy on treatment of R&D investments.	42-1 ☐	2 ☐	3 ☐	4 ☐	43-1 ☐	2 ☐	3 ☐	4 ☐
U.S. currency in foreign markets.	44-1 ☐	2 ☐	3 ☐	4 ☐	45-1 ☐	2 ☐	3 ☐	4 ☐
Impact of federal budget deficit.	46-1 ☐	2 ☐	3 ☐	4 ☐	47-1 ☐	2 ☐	3 ☐	4 ☐
Other fiscal or monetary issues ________ ________	48-1 ☐	2 ☐	3 ☐	4 ☐	49-1 ☐	2 ☐	3 ☐	4 ☐

7. Looking back at the preceding six groups of issues, please rank each in order of importance, 1 (most important) through 6, to your firm and to the nation, relative to international economic competitiveness:

	a. *To your firm*	b. *To the nation*
Educational and human resources policies and practices	50____	56____
Research and development resources	51____	57____
Transfer of technology	52____	58____
Federal regulatory policy	53____	59____
U.S. trade policy and practice	54____	60____
Fiscal and monetary policy	55____	61____

Public-Private Cooperative Programs

Both the states and the federal government have set out certain programs and incentives intended to complement the private sector's R&D effort. This section of the questionnaire seeks to determine the extent to which you are aware of such programs, make use of them, and what your views are on the value of these programs. Listed below are some of the principal ways in which state governments and educational institutions can cooperate with private sector firms in their research and development activities. We are interested in learning the extent to which you are aware of these activities in the states in which you have R&D facilities, whether you have made use of such programs, your interest in and evaluation of such programs.

State Initiative/ Program Description	Level of Interest in Such Program	Aware of Specific Program	Have Used Specific Program	Assessment of Specific Program's Value
	(Rank 1 to 5; 1=highest)	(Check if yes)	(Check if yes)	(Rank 1 to 5; 1=highest)
Instructional and research equipment donations to universities.	10-____	11- ☐	12- ☐	13-____
Industry-university joint research projects.	14-____	15- ☐	16- ☐	17-____
Matching grants for research and development	18-____	19- ☐	20- ☐	21-____
State R&D tax credits.	22-____	23- ☐	24- ☐	25-____
Bond issues to support state R&D and education initiatives.	26-____	27- ☐	28- ☐	29-____

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State Initiative/ Program Description	Level of Interest in Such Program	Aware of Specific Program	Have Used Specific Program	Assessment of Specific Program's Value
	(Rank 1 to 5; 1=highest)	(Check if yes)	(Check if yes)	(Rank 1 to 5; 1=highest)
Skills retraining for production, technical, or research staff.	30-____	31-☐	32-☐	33-____
Industry-university personnel exchange programs.	34-____	35-☐	36-☐	37-____
Student internship or cooperative programs.	38-____	39-☐	40-☐	41-____
State patent and licensing assistance services.	42-____	43-☐	44-☐	45-____
Technical consulting services (feasibility studies, product testing, prototype development).	46-____	47-☐	48-☐	49-____
Technical extension services (state field staff who provide technical advice and support.)	50-____	51-☐	52-☐	53-____
State libraries and data bases.	54-____	55-☐	56-☐	57-____
Technical data services (on faculty research, venture opportunities, etc.).	58-____	59-☐	60-☐	61-____
State liaison to provide access to federal laboratory and research facilities.	62-____	63-☐	64-☐	65-____
Start-up, venture, or seed capital.	66-____	67-☐	68-☐	69-____
Funds for product development, testing, prototypes, etc.	70-____	71-☐	72-☐	73-____
Investment capital for facilities, machinery, and equipment.	74-____	75-☐	76-☐	77-____
Site location assistance for R&D facilities.	10-____	11-☐	12-☐	04 / 8-9 13-____
Research and science parks.	14-____	15-☐	16-☐	17-____
"Incubator" facilities for start-up firms (low rent office/lab space).	18-____	19-☐	20-☐	21-____
Pooling of regional research resources.	22-____	23-☐	24-☐	25-____
Other forms of assistance. ____________ ____________	26-____	27-☐	28-☐	29-____

Policy Considerations

This section of the survey provides you with an opportunity to comment in your own words on ways in which the state and federal government can be of assistance to the private sector in fostering research and development.

1. In particular, what are the most important ways in which the universities can be of assistance to your company's R&D program?

____

____ 30-31

____ 32-33

____ 34-35

____ 36-37

2. What are some important ways in which you believe your company can be of assistance to university research and education programs? ______________________________ 38-39

____ 40-41

____ 42-43

____ 44-45

3. What measures, if any, should the U.S. government take to improve U.S. technological innovation? ______ 46-47

____ 48-49

____ 50-51

____ 52-53

4. Do you believe individual states should "target" certain technologies and take steps to encourage that technology within the states?

54-1 ☐ Yes
2 ☐ No

Comment: ____

____

____

5. Do you believe that certain high tech "infant" industries should receive temporary (5-year) trade protection from foreign competition until those industries have matured enough to withstand such competition?

55-1 ☐ Yes
2 ☐ No

6. Do you anticipate that your firm will experience any shortages of science, engineering and technical personnel during the next decade?

56-1 ☐ Yes
2 ☐ No

If yes, at which level of education and/or experience do you expect the most severe shortages to occur?

57-1 ☐ Ph.D. level
2 ☐ Masters level
3 ☐ Bachelors level
4 ☐ Technician level

(b) What steps do you believe should be taken to help alleviate such shortages? (Please comment below.)

______________________________ 58-59
______________________________ 60-61
______________________________ 62-63

7. Current data indicate that a lower percentage of students are selecting engineering and science careers. What factors do you believe are most responsible for this decline in interest? (Please comment below.)

______________________________ 64-65
______________________________ 66-67
______________________________ 68-69

8. What do you regard as the three most significant barriers, from all sources, to technological innovation within your industry (not your company)?

1. ______________________________ 70-71
2. ______________________________ 72-73
3. ______________________________ 74-75

9. Should further steps be taken to foster joint R&D ventures among competing companies, and/or universities, and what steps would you recommend?

______________________________ 76-77
______________________________ 78-79
____

Thank you for your help in this research. Please make sure that your name and address are on the front cover of the questionnaire so that we may send you a copy of the survey results.

APPENDIX II: LIST OF SPEAKERS AND PANELISTS PARTICIPATING IN THE REGIONAL MEETINGS

APPENDIX II

Economic Competitiveness: Redefining Role for Government, Industry and Universities
April, 1987

Speakers and Panelists

Taylan Altan
Director
Center for NET Shape Manufacturing
Ohio State University

Warren Baker
President
California Polytechnic State Univ.

Edward Barr
Chairman
N.J. Commission on Science and Technology

Michael Beug
Academic Dean
Evergreen State College

Lynn Blake
Director
Centers of Excellence Program
State of Utah

Erich Bloch
Director
National Science Foundation

Elaine Bond
Senior Vice-President
Chase Manhattan Bank

Suzanne Brainard
Director
Corporate Communications
Seattle Silicon

Lewis Branscomb
Director
Science, Technology and Public Policy Program
Harvard University

Hal Burlingame
Senior Vice-President for Human Resources
AT & T

Raymond Bye
Director
Office of Legislative and Public Affairs
National Science Foundation

Kermit Campbell
Vice-President for Communications and Public Affairs
Dow Corning Corporation

Dwight Carlson
President
Perceptron, Inc.

John F. D'Aprix
President
University City Science Center

John DiBiaggio
President
Michigan State University

Wayne Embrey
Deputy Director
Oregon Research and Technology Development Corporation

Saul Fenster
President
New Jersey Institute of Technology

The Honorable Booth Gardner
Governor
State of Washington

William Gerberding
President
University of Washington

Robert Greenkorn
Vice-President for Research
Purdue University

Robert Gross
Dean of Engineering
Columbia University

Burton Jonap
Vice-President
Connecticut Product Development Corporation

Bruce Kasson
Vice-President for Marketing and Customer Operations
Cray Research

The Honorable Thomas H. Kean
Governor
State of New Jersey

David Kennedy
Program Administrator for Curriculum
Office of Superintendent of Public Instruction
State of Washington

David Longanecker
Executive Director
Minnesota Higher Education Coordinating Board

Walter Luscutoff
Executive Vice-President
Flow Industries

George Mackaness
President
Squibb Institute for Medical Research

Edith Martin
Vice-President for Technology
Boeing Company

E. Patrick McGuire
Executive Director
Corporate Relations
The Conference Board

John P. McTague
Vice-President for Research
Ford Motor Company

John Moore
Deputy Director
National Science Foundation

Gregory Olsen
Director
Epitaxx

Peter Plastrik
President
Michigan Strategic Fund

Doug Ross
Director
Michigan Department of Commerce

Ian Ross
President
AT&T Bell Laboratories

John Schade
Director
Research and Technology Park
Washington State University

Harold Shapiro
President
University of Michigan

Aaron Shatkin
Director
Center for Advanced Biotechnology
N.J. University of Medicine and Dentistry

Hunter Simpson
General Partner
Trinus Partners

Malcolm Stamper
Vice-Chairman
Boeing Company

Jacob Stucki
Corporate Vice-President
Upjohn Corporation

Louis Tornatzky
Director
Center for Social and Economic Issues
Industrial Technology Institute

Barbara Waters
Deputy Counsel
Executive Office of Economic Affairs
Commonwealth of Massachusetts

Donald Williams
Director
Technology Transfer
Battelle Pacific Northwest Laboratories

APPENDIX III: ISSUE PAPER

RESEARCH AND EDUCATION IN ECONOMIC COMPETITIVENESS: NEW ROLES FOR GOVERNMENT, INDUSTRY AND UNIVERSITIES

A Discussion Paper

Prepared by:

Center for Policy Research and Analysis
National Governors' Association
444 North Capitol Street, N.W.
Washington, D.C. 20001

April, 1987

PREFACE

The National Governors' Association (NGA), with support from the National Science Foundation, has joined with the Conference Board in a cooperative project designed to examine the role of research and education in economic competitiveness. During the month of April, we will be convening Governors, key industry executives, other state and federal policymakers, and university officials to examine the changing work of their institutions in supporting research, innovation and the utilization of new technology.

This discussion paper was prepared by the National Governors' Association's Center for Policy Research to provide background information to participants in four regional conferences. It focuses on three major issues: meeting human resource needs, meeting research and development needs, and commercializing new technology. The information contained in the paper is based on past work conducted by the NGA. Following the conferences, the paper will be revised substantially to reflect the input, conclusions and recommendations from the conference participants.

TABLE OF CONTENTS

INTRODUCTION

The ability of U.S. firms to compete in world markets depends critically on their ability to continually generate new ideas and use new technologies. To remain competitive, the U.S. must both remain at the cutting edge of science and technology, and adopt and implement the new technology developed. Its ability to do so depends on the availability and quality of scientists and engineers to conduct research and to respond to the needs of a rapidly changing economy.

The U.S. has long been the world leader in advancing knowledge in areas of science and technology. There is concern, however, that the U.S. is losing its dominance.

- While U.S investment in research and development is the highest of any country in the world, U.S. investment in civilian research and development as a fraction of GNP is less than that of Germany and Japan. In 1983 the U.S. invested 1.91 percent of GNP in non-defense R & D while Germany invested 2.47 percent and Japan 2.60 percent.

- The proportion of the workforce engaged in research and development among our competitors has increased sharply since 1965, and is beginning to approach U.S. levels. Japan and Germnay have doubled their technical workforce during this period.

It is clear that United States' superiority in science and technology can no longer be taken for granted. If we are to maintain our economy competitive with other countries we must invest in our research infrastructure and facilitate the transfer of knowledge and resources to new applications, new products and new processes.

This paper describes current developments in science and technology education, collaborative research, and technology transfer. It also raises a number of questions regarding government/university/industry roles in relation to science and technology policies.

MEETING HUMAN RESOURCE NEEDS

A major strength of the United States over the years in maintaining its competitive position has been its human resources. The high quality of our scientists and engineers, coupled with a highly skilled work force, has played a critical role in supporting technological innovation. Recent trends, however, are disturbing. The National Science Foundation reports that twenty years ago the U.S. had far more scientists and engineers per capita than any of our competitors. Today that is no longer the case. The proportion of students pursuing science and engineering degrees is declining. Because of demographic changes, the numbers of students available to pursue science careers will decline from now until the 1990s.

In addition to these trends, concern has arisen regarding the quality of science and technical education at the elementary, secondary and college level. A recent report by the National Science Board found serious deficiencies in undergraduate science, mathematics and engineering education.[1] These include:

- serious deterioration in laboratory instruction;

- faculty members unable to update their disciplinary knowledge and to make use of computers and other advanced technologies; and

- courses and curricula which are out of date, unimaginative, poorly organized for students with different interests, and fail to reflect recent advances in the understanding of teaching and learning.

But the problem of meeting human resource needs extends beyond the need for research scientists and engineers to the skill needs of the overall work force. New technologies require a greater range of skills, as well as new skills, for the average worker.

New Investments in Education

Both state and federal governments have undertaken initiatives to improve the quality of science and engineering education at the pre-college, college, and graduate levels. State governments have, in addition, become increasingly active in supporting technical education and retraining.

Federal Initiatives

One of the basic missions of the National Science Foundation is to improve science, mathematics and engineering education. NSF's FY 1988 budget request proposed several initiatives to improve science and engineering education at pre-college, college and graduate levels. Pre-college activities, which include hands-on research experience to encourage science and engineering careers through enrichment activities for talented high school students, and development of improved teaching materials, would be funded at $68 million under the new budget. An additional $70 million would be used to improve the quality of undergraduate instruction. New activities include:

- instrumentation and laboratory instruction;
- student research participation;
- faculty enhancement; and
- curriculum development in calculus and engineering.

NSF also operates programs designed to encourage promising young scientists and engineers to remain in academic careers (Presidential Young Investigator's Award Program) and to encourage women and minority students to pursue science and engineering careers.

The Department of Education also provides support for improving science and mathematics education. Funded at $80 million for FY 1987, this program provides grants to states to offset part of the cost for training and re-training mathematics and science teachers at the secondary level.

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1 Undergraduate Science, Mathematics, and Engineering Education, National Science Board, March, 1986, p. 2.

Federal agencies, for the most part, support graduate and post-doctoral education through research project support and competitive fel. wships. In 1985, NSF, the National Institutes of Health, the Department of Defense, and other federal agencies, supported 20 percent of all full-time engineering and science graduate students in doctorate granting institutions.

State Initiatives

In order to improve the quality of mathematics and science instruction at colleges and universities, faculty and students must have access to up-to-date facilities and equipment. To respond to this need, states have increased their investments in new capital facilities at state colleges and unversities. Estimates of unmet demand for new construction and renovation of research facilities range from $5 to $20 billion in the next ten to twenty years. Regardless of the exact estimate, there seems to be widespread agreement that there is a need to modernize deteriorating and obsolete research facilities at universities and colleges.[2]
Examples of state actions include:

- In November 1984, New Jersey voters passed a $90 million Jobs, Science and Technology Bond issue. Approximately half of these funds were used to upgrade technical and engineering facilities at the state's universities and community colleges.

- In 1985, Oregon passed a lottery bill which required that the proceeds be dedicated to economic development. Fifty percent of the total amount projected to be raised was earmarked for higher education. Twenty-three million out of $44 million was designated for capital construction projects at Oregon's major universities.

- Michigan provided $12 million to construct a $17.3 million facility for its Industrial Technology Institute which includes office and laboratory space for more than 250 employees. An additional $5.3 million was raised from private sources.

States have also been active in providing additional training and retraining for technicians. In South Carolina, for example, the state directed six technical colleges to develop education expertise in specific scientific areas. The targeted technologies and the location of the programs were based on both the strengths of the school and the state's economic development plan. At Piedmont Technical College, a two-year Associate Degree program in Automated Technology has been established. The program is expected to become a "prototype" for Associate Degree programs in robotics. The Robotics Resource Center at the College also conducts plant-specific, on-the-job industry raining and re-training.

In addition to these technical education programs, efforts to improve science and mathematics education at the K-12 level figure prominently in state educational reform initiatives. States have increased standards, expanded the number of mathematics and science courses required of students,

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2 Academic Research Facilities: Report of a Conference July 22 - 23, 1985, Government/University/Industry Research Roundtable, 1986, p 1.

increased the amount of time devoted to mathematics and science, established more rigorous graduation requirements and inserted computer literacy into the curriculum. In addition, some states have established special science and mathematics high schools, scholarships for students to pursue math and science undergraduate degrees and recruitment programs for science and math teachers.

Business Support for Education

In the past thirty years, corporate support of colleges and universities has risen from approximately $40 million to more than $1 billion. In addition to the direct support of colleges and universities, business corporations currently provide an estimated $350 million in other educational aid -- scholarships and fellowships to students, grants to precollege institutions, and support of many educational activities and organizations.[3]

Specific programs of educational support differ widely from one company to another. Many businesses provide scholarships and fellowships directly to students or through third parties. Cooperative education programs allow students to alternate periods of work and study.

Businesses also provide an array of programs designed to enable employees to upgrade their skills. These include adult education programs for corporate employees, with whole or partial tuition refunds upon the successful completion of academic work; organized instruction programs for groups of corporate employees, held somtimes on the campus and sometimes on corporate premises, special advanced training programs for corporate executives; contract arrangements to retrain workers with obsolete skills; and vocational programs to upgrade the skills of employed workers.

More recently businesses have become involved in helping colleges and universities purchase equipment and construct research facilities. At George Mason University in Virginia, e.g., local firms provided $3 million for endowed professorships and fellowships and donated equipment to support a newly established School of Information Technology and Engineering. Forms of business participation in educational partnerships at the university level have changed recently and include cooperative programs involving graduate and undergraduate students in addition to faculty members.

Discussion Questions

While there is general agreement regarding the importance of science and mathematics education to the nation's future competitiveness, there is currently no national strategy for addressing this need. Workshop participants are encouraged to consider the following questions with regard to meeting human resource needs.

How are the human resources that are needed by the economy being changed by technology? What can states do to assure that these needs are met? What should universities do to assure that these needs are met?

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3 Corporate and Campus Cooperation: An Action Agenda: A Report by the Business-Higher Education Forum, May, 1984, p. 11.

What is the responsibility of the private sector in meeting human resource needs? How can private businesses play a role in improving curricula and seeing that courses are up-to-date?

How should science, mathematics and engineering education be supported at the pre-college, college, and graduate level? What are gaps in current programatic support? What are the respective roles of government, universities, and industry?

What must we do to interest more young people in science and engineering?

How great is the need for training and retraining for technicians and production workers? What role should states play in providing such training?

Investing in Research and Development

The United States spending on research and development in 1987 is estimated to be $125.2 billion. Roughly half is provided by the private sector, with the federal government providing the remaining half. States and other sources provide 3 percent of total expenditures. While the percentage of resources dedicated to basic research, applied research and development, 12 percent, 21 percent and 67 percent respectively, have remained relatively constant over the past ten years, industrial support for applied research has increased and the federal government has switched a greater percentage of resources to basic research.

Approximately 51 percent of federal funding for basic research flows through the university system, by means of grants or contracts which are awarded on a competitive basis for specific projects. The National Science Foundation and the National Institutes of Health, for example, provide 74 percent and 67 percent of their expenditures on basic research to universities. There are also examples of close, long-term relationships between federal agencies and research universities. The Departments of Energy and Defense, for example, have long-term contractual links with universities for the performance of research and the operation of research laboratories.

Most of the federal expenditures for applied research and development are targeted towards military purposes, space exploration, and mission-oriented activities. The federal investment in applied research and development in non-defense areas is estimated to have declined by 17 percent and 55 percent, respectively, in constant dollar terms between 1980 and 1985. Overall, there was a 26 percent growth in real terms in Federal support for basic research between 1980 and 1985, a 7 percent decline in applied research, and a 44 percent increase in support for development. Between 1980 and 1985, industrial support of applied research grew at an average annual rate of 10.2 percent in constant dollars.

New Partnerships Emerge

The past several years have witnessed an explosion of new research partnerships. For universities, partnerships with industry have been spurred by the prospect of additional research dollars at a time when federal dollars are in increasing demand. In addition, universities have benefited from donations of state-of-the-art equipment, and increased opportunities for both students and faculty to interact with industrial researchers. While in the past many such partnerships focused on financial support to universities or exchanges of personnel, today's partnerships are based on active interaction between industry and university researchers, who work side by side in laboratories on jointly defined research objectives.

Industry participation in these alliances with universities has been motivated by a need to develop and adopt new technological processes and products quickly and to secure access to innovative researchers and fresh ideas. The rapid pace of technological change has caused a blurring of the lines between basic and applied research thus encouraging industry to seek involvement in university research programs.

One of the best known examples of an industry/university joint venture is the Monsanto/Washington University program. In an effort to expand into the biotechnology market, Monsanto in 1982 signed a joint research agreement with Washington University in St. Louis under which Monsanto will pay the University $62 million over eight and a half years. Under the program, university and industry researchers are working together in an effort to speed the application of basic research findings into products for market.

An example of an all industry-supported research partnership is the Semiconductor Research Corporation, a non-profit consortium of U.S. companies. The corporation was established to strengthen generic research capability in semiconductor technology. The Corporation has sixty members and spends 90 percent of its budget to support university research projects.

Government policies, at both the state and federal level, have played a part in encouraging these relationships.

State Actions

State support for research and development is a fairly recent phenomenon. While state governments have long provided core funding for state colleges and universities, states are now providing direct support earmarked for specific research and development activities at both public and private institutions. The predominant mechanism used to support research and development is the creation of university-based technology research centers, sometimes referred to as centers of excellence and/or advanced technology centers.

University technology research centers are vehicles for conducting research in a specific technological area. Usually the state identifies those areas in which the university system has expertise and/or that are particularly pertinent to the state's major industries. A research center is established to focus on these technologies with the state serving as a catalyst to bring the resources of the private sector and university together.

A 1985 NGA survey identified thirteen states that were developing technology research centers. Eleven states operate matching grant programs for applied research and development. Examples of state activities in this area include:

Michigan's Industrial Technology Institute (ITI) is one of three research centers of excellence established by the state. ITI's roles and functions include performing basic and applied research in industrial automation and computer integrated manufacturing; developing new techniques, processes and decision-making tools for the factory of the future; disseminating information on emerging technologies, and fostering new industrial development in production of hardware and software for automated manufacturing.

The Washington Technology Center provides a focus to conduct original research, train advanced research students, and create commercially promising technology for use in Washington state. It brings together researchers from industry and academia to concentrate on plant bio-technology, computer science, advanced materials, integrated circuits/optics, and micro-sensors.

Pennsylvania's Ben Franklin Partnership Program. The Ben Franklin Partnership Program provides grants for applied research and development activities and technical and financial assistance to entrepreneurs and existing businesses. Its largest program is the Challenge Grant Program which established four Advanced Technology Centers. Each center is a consortium of private sector, labor, research universities, and other higher education institutions, and economic development groups. The centers conduct joint research and development projects, sponsor education and training activities, and provide entrepreneurial assistance services.

Federal Actions

Recent federal efforts to promote greater industry/university linkages include the newly established Engineering Research Centers program of the National Science Foundation, the University Research Initiative of the Department of Defense, and the Administration's proposal to establish Basic Science and Technology Centers.

The purpose of NSF's ERC program, established in 1985, is to develop fundamental knowledge in cross-disciplinary engineering fields that will enhance the economic competitiveness of the U.S. and prepare future engineers. The centers support research and promote close industry/university work relationships. Thirteen centers were funded in the first three years of the program. The FY 1988 budget requests $48 million, up from $30 million in FY 1987, which would provide funding for five additional ERCs.

The Administration has proposed expanding the ERC concept to Basic Science and Technology Centers in a wide range of scientific research fields in the FY 1988 budget. These centers would be established in fields such as computer and information sciences, materials science, and biology and biotechnology. The FY 1988 budget includes approximately $40 million to fund five to ten centers.

The Department of Defense has created a University Research Initiatives Program, a multi-component effort designed to strengthen the capability of universities to perform research and to educate scientific and engineering personnel in key disciplines important to the technologies underlying a strong national defense.

In FY 1986 and 1987, the Department spent $105 million to fund 86 multi-disciplinary research efforts at universities. An additional $20 million was used to fund fellowships, young investigator awards, and scientific exchange programs between university and Department of Defense laboratories. Ninety-three million dollars has been requested in the FY 1988 budget for the University Initiatives Program.

Discussion Questions

Despite the flurry of activity in the area of university/industry government research partnerships, a number of issues remain unresolved.

What is the level of commitment on the part of both business and industry to the university partnerships described above? Do industrial partners feel they have a stake in the outcomes of these efforts? Are small and medium-sized companies involved? If not, what are the barriers to their participation?

How effective have these efforts been in generating commercial results? To date, evaluative data on these efforts have been limited. How can their impact be measured?

Is there a state role in supporting basic research? How might state efforts to promote applied research and development be strengthened?

What is the relationship between state and federal efforts? Are they duplicating, complementing or supplementing each other? How could federal and state efforts be better integrated?

Is there a danger of states wasting resources by targeting similar technologies or does this promote healthy competition within the research community?

COMMERCIALIZING NEW TECHNOLOGY

A strong research and development base, in and of itself, however, is not sufficient. There is an additional need to ensure that the knowledge and technology developed are actually used. In fact, this is the area in which U.S. performance is viewed as weaker than many of our major competitors. For example, the videocassette recorder, invented in United States in 1956, was never commercialized here; today not one VCR is produced in the U.S. and two Japanese firms, Sony and Matsushita control 90% of the U.S. market. There is also concern that American manufacturers have been slow to automate. In 1986, for the first time, the U. S. ran a trade deficit of high-technology products.

The ever increasing pace of technological change presents a challenge for policymakers: how to facilitate the diffusion of new knowledge and technology to the widest possible audience. Public policies to encourage such diffusion, often referred to as "technology transfer" programs, are not new. The agricultural extension service, which dates back to the early 1900's, represents the largest public investment in a diffusion system in the world.

There are two primary ways in which the public sector can seek to accelerate the pace of diffusion. The first is by facilitating the flow of information from researchers to potential users. The second is by providing direct assistance to entrepreneurs and technological innovators as they seek to apply new knowledge in the marketplace.

Facilitating Information Exchange

The federal government over the years has undertaken a number of programs to disseminate the results of federal research activities to potential industrial users. NASA's Technology Utilization Program, for example, was established in 1962 to disseminate research on aerospace technology to private industry. As part of the TU program NASA established nine university-based Industrial Application Centers to offer information services, workshops, and technical assistance to industrial clients.

States have also established mechanisms for information exchange, setting up programs to link businesses with information and expertise on technological issues. Often such programs are designed to provide small businesses with access to the resources of the state's university system. Examples of state initiatives in this area include:

- Virginia's Commonwealth Technology Information Service, a data base used to identify, store, manage and actively disseminate information on Virginia's technology resources.
- Ohio's Innovation Exchange Network (TIE-IN) is a statewide interactive database which includes information on faculty research activities throughout the state, venture opportunities and patent information.
- Illinois Resource Network is a statewide electronic directory which can provide names, campus addresses, and educational background of 6,000 university faculty members. Through a key work or phrase, the Illinois Resource Network can help identify specialized consultants.

Assisting Businesses and Entrepreneurs

Another alternative to facilitate the innovation diffusion process is for the public sector to undertake a more active role in encouraging businesses to adopt new technology or develop new product lines and in encouraging individuals to start new firms.

Federal Aid to Business

Although the federal government provides some assistance to small businesses, businesses located in distressed areas, and businesses owned by disadvantaged or minority persons, there are few federal programs designed specifically to aid entrepreneurs and/or technology-based firms. One exception is the federal Small Business Innovation Research (SBIR) Program. In 1982, the Small Business Innovation Development Act mandated that each federal agency with an external research and development budget exceeding $100 million spend a specified percentage (up to 1.25 percent) of such budget via a special SBIR program.

Under the SBIR program, federal agencies request proposals from small businesses in response to solicitations outlining their research and development needs. After evaluating the proposals, each agency awards grants for determining the technical feasibility of the research and development concepts proposed. If found to be feasible, the firms can then receive funds for full-scale research and development. In 1985, twelve agencies awarded $196 million under SBIR programs. The SBIR program has proven to be very popular; so much so, that several states have developed programs which piggyback on the federal program.

State Aid to Business

States have developed a variety of programs to aid existing firms seeking to introduce a new product, adopt a new process, and encourage new spin-offs. Most of these programs include an information dissemination component but many provide in-depth counseling and technical assistance as well.

For example, at least ten states currently operate industrial extension services, which vary greatly from state to state.

- The Michigan Technology Deployment Service (TDS) was established in 1985 to assist companies that are considering adoption of new, computer-based manufacturing tools and methods. TDS operates with a small central staff and several field representatives and training associates located across Michigan. The TDS field representatives are experienced managers and engineers with strong backgrounds in private industry. TDS training associates are senior staff at Michigan community colleges who have broad experience in designing customized training programs for manufacturing clients.

- The Ohio Technology Transfer Organization provides Ohio businesses with direct access to new technology and research through a statewide network of thirty-four technology transfer agents based at two year colleges.

- Maryland operates regional technology extension offices in conjunction with the Engineering Research Center at the University of Maryland. Offices are staffed by industrially experienced engineers who respond to companies providing individual technical advice and problem solving.

Other states have set up centers which provide similar services. In addition to assisting existing firms, however, they may also assist individuals seeking to start a new company. To ensure that entrepreneurs are able to commercialize their products, a spectrum of support services can be provided. Entrepreneurial assistance programs often provide technical assistance, limited testing market evaluation, and general business and management advice.

States have also set up incubators to provide ongoing support for new businesses. Incubator facilities provide low-rent office and lab space for entrepreneurs or early start-up firms. On-site support services such as office support and computer access are also frequently provided along with on- or off-site management and technical assistance on a referral basis. While incubators can serve a variety of firms, they are more often targeted to technology-based companies.

In 1983, the North Carolina legislature passed a $2 million High Technology Jobs Act to encourage entrepreneurship among small businesses in the high technology sector. The act created the North Carolina Technology

Development Authority to implement a seed capital program and establish incubator facilities. The state provides one-time matching grants to local governments to establish incubator facilities.

A final area in which states have become increasingly active is providing start-up and early-stage financing for new, technology-based businesses. State programs provide venture capital where private sources are absent (venture capital companies tend to invest in geographic areas with an existing concentration of technology-based firms), and/or to meet capital needs not normally serviced by private venture capitalists. A 1986 study by the Kansas Department of Development identified twenty-eight states that support some type of venture capital program.

Role of the Private Sector

While the public programs described above can be important in creating a supportive climate for technological innovation, the actual decision of whether or not to adopt a new manufacturing process or market a new product is essentially the decision of an individual firm. Recent newspaper and magazine articles have argued that some of the competitive difficulties of U.S. firms are due to poor management decisions spurred by short-term horizons of management and demands for immediate financial returns.

An Office of Technology Assessment study is examining collaborative research efforts to determine their effect in achieving commercialization. The preliminary analysis indicates that one of the factors contributing to low levels of commercialization lies within individual firms. It appears that there is often a gap between those persons responsible for research and new product design on the one hand and those responsible for manufacturing, operations and marketing on the other. Thus, research findings may never find their way to the production floor.

Discussion Questions

While there is general agreement on the need to speed the diffusion of new research findings througout the economy, there is no general agreement on how this can best be accomplished. Issues for your consideration include:

What are the major barriers to the adoption of new technological products and processes? How might these barriers be removed?

What type of assistance is most needed by entrepreneurs seeking to start a new firm or introduce a new product? Is assistance to entrepreneurs an appropriate activity for state governmen ? Should existing federal buisness assistance programs be targeted to the needs of new, technology-based firms?

What steps should be taken to encourage existing manufacturers to adopt new technology? Are industrial extension services an effective mechanism for improving the utilization of new technology?

Are there actions individual companies should take to speed the commercialization process?

How can universities improve their technical assistance to the local business community?

NEW ROLES FOR GOVERNMENT, INDUSTRY AND UNIVERSITIES

The above examination of the United States' research system reveals that changes are occurring in the very nature and conduct of research. Research is producing new knowledge at an accelerating pace; the time lag between basic and applied research is becoming shorter. It is becoming increasingly multi-disciplinary, especially as new areas of specialization, such as biotechnology, are arising which cross traditional disciplinary boundaries.

The practice of research has changed as well. It is now commmon for research to require eleborate and expensive indtruments and facilities. These changes are placing increasing demands on our research infrastructure, i.e. our universities, businesses, and workers, as the country seeks to maintain its leadership role in science and technology. To meet these needs will require a new partnership between state and federal governments and between industry and universities.

New Roles in Support of Education

To meet our future human resource needs the following issues must be addressed:

- actions must be taken to encourage students to pursue science and engineering careers;

- efforts must focus on improving science and mathematics education at all levels; primary and secondary, college, and graduate level;

- training, retraining and continuing education programs must be established to maintain a technically skilled work force; and

- investments must be made in the nation's colleges and universities.

Government, industry and universities must each play a role in addressing these needs.

The federal government will continue to support graduate and undergraduate education, particularly by providing both students and faculty with the opportunity to participate in individual research projects, by supporting graduate fellowships, and by encouraging participation in multi-disciplinary centers, such as Engineering Research Centers and the newly proposed Science and Technology Centers. An additional role for the federal government may be to reinforce its efforts, for example, NSF's EPSCOR Program, to assist those colleges and universities with less well-developed research capacity to build strengths in specialized technological areas.

It may also be appropriate for the federal government to expand its role in supporting improved mathematics and science education at pre-college levels by supporting teacher training, curriculum and materials development, and demonstration programs.

States will play a critical role in meeting human resource needs, as state governments have primary responsibility for funding K through 12 education and for providing the core support for state university systems. States must therefore be encouraged to:

1) continue efforts to improve elementary and secondary education, particularly in areas of science and mathematics;

2) use state community college systems and vocational-technical schools to provide training and retraining to meet the needs for a highly trained and adaptable work force;

3) increase support for university systems, including investing in capital facilities, as well as efforts to retain highly competent faculty by means of endowed chairs and professorships; and

4) develop programs to encourage minorities and women to enter science and mathematics programs.

Universities are clearly a dominant actor since they are responsible for the quality of graduate and undergraduate education. Universities should encourage greater interaction between their faculty and industry researchers through university/industry personnel exchange programs and by an incentive structure which encourages cooperative ventures. Students must also be given the opportunity to participate in joint research and development efforts. Universities can also provide important support for secondary teachers offering workshops and courses to improve and up-date their skills and can provide programs, workshops and lectures for gifted students.

Industry has an important role to play as well. Although education has traditionally been regarded as a "public" responsibility, private firms have an interest in supporting an educational system which will produce skilled workers as well as scientist and engineers. Industry can play an important role in defining skill needs, helping with curriculum development, and providing assistance to keep programs up-to-date. Industry can also commit resources to universities, participate in partnership programs, offer internships to students and participate in cooperative research programs that further many of these objectives.

New Roles in Research and Development

The issue of research and development and commercialization are closely related. The major challenge is to support not only excellence in U.S. research but the most effective utilization of our research findings. To do this, we must:

- breakdown barriers between university researchers and industry
- increase private sector involvement and support of collaborative research
- integrate research and product development with manufacturing, production and marketing functions;
- encourage greater commercialization of research findings; and
- establish a joint federal/state partnership in support of research and development.

A federal role in research and development, in addition to providing funding for basic and mission-oriented research and development, is to establish the context within which research is undertaken. The federal government is in a unique position to monitor ongoing research, identify national priorities and coordinate efforts throughout the country.

State governments continue to expand their activities in support of research and development and commercialization. States should be encouraged to act as catalysts and facilitators by providing information on current research and industry needs, setting up mechanisms for industry/university interaction, and serving as a focal point for programs and services. In addition, state governments can provide incentives to encourage greater private industry support and involvement in collaborative research and use state funds to leverage additional funding for applied research and development projects.

For its part, industry should be encouraged to increase its investment in university research, increase their commitment to collaborative research and participate in industry-wide research efforts. Firms should also be encouraged to establish greater linkages between management, design and production functions within their organizations and to examine the issue of commercialization.

Universities should market their services to the private sector, acting as a resource for local businesses. They can also provide technical assistance to innovators and technological entrepreneurs. Many universities, for example, operate incubator facilities and manage industrial parks. Universities should also be encouraged to change their incentive structures to encourage greater faculty involvement in collaborative research.

Conclusion

To meet the challenge of economic competitiveness, the United States as a nation must make a long-term commitment to its education and research system. But we will achieve our goals of maintaining our leadership position in science and technology and speeding the diffusion of new knowledge and technology throughout our economy only if government, universities and industry work together. This will require an openness on the part of each party and a willingness to redefine relationships and experiment with new ways of doing business. The purpose of this conference is to begin the process of defining these new relationships.