1988

A View from the National Science Board

THE STATE OF U.S. SCIENCE AND ENGINEERING

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The National Science Foundation was established by the Congress to support scientific and engineering research and education. It is also charged with evaluating the state and needs of science and engineering. In carrying out this latter responsibility, the National Science Board – NSF's policymaking body – publishes a biennial report on science and engineering indicators. The indicator report documents quantitatively the health and achievements of the entire enterprise. *Science and Engineering Indicators 1987*[*] provides background for the National Science Board's views on the state of U.S. science and engineering.

There are many signs of strength, according to the latest indicators. For example:

- Over the last eight years real growth has occurred in research and development (R&D) and in basic research supported by both the Federal Government and industry. R&D as a percentage of gross national product (GNP) has grown and is now at 2.76 percent, the highest level since the late 1960's.
- The scientific and engineering workforce has nearly doubled in the last decade, increasing four times as rapidly as total U.S. employment.
- **Never in the history of science have there been so many opportunities in science and engineering, as exemplified by areas such as superconductivity and biotechnology.**
- The United States exports more high-technology goods than any other country.
- The American public overwhelmingly believes that scientific research has brought more benefit than harm to our society and that the Federal Government should support scientific research.
- **The Administration has provided strong support for R&D. The President has stated that advancing science and technology is fundamental to U.S. competitiveness.**
- Governors in many states have increased their investment in R&D and education to nurture economic growth. Local governments have acted to enhance the teaching of mathematics and science in their schools.

[*] National Science Board, SCIENCE AND ENGINEERING INDICATORS 1987 (U.S. Government Printing Office, Washington, D.C., 1988) is the Board's most recent report to the President and the Congress.

These are indicators of health and support for U.S. science and technology. They reflect a long-standing acceptance by most Americans of the important role of science and technology in our society. Other indicators, however, show a different, less optimistic, situation and portend a future that may not provide the economic growth and increasing standard of living we have come to expect. Some examples:

- Our industries, the high-technology sector included, face serious competitive challenges. In 1986, the United States for the first time imported more high-technology products than it exported, exacerbating the negative trade balance in other manufactured goods.
- Other nations have greatly increased their capabilities in science and technology. As a result, the United States faces increased competition not only in international trade but also in scientific and engineering research. Increased Japanese investments in basic research are a case in point.
- The number of U.S. patents granted to U.S. nationals is steady, while patents granted to foreign nationals are increasing (now up to 40 percent).
- Both participation and achievement by U.S. elementary and secondary students in science and mathematics are lagging compared with previous years and with other countries.

We can no longer take American scientific and technological dominance for granted. Not since Sputnik in 1957 has there been so much cause for concern about the adequacy of our science and technology base and our ability to capitalize on scientific and engineering strengths to sustain industrial leadership. Government, industry, and academic leaders agree that science and engineering education and research are important to our future. Concerted efforts of institutions at all levels and by all sectors will be required to provide the needed programs and activities. We need to act with respect to our human resource base, the financial resources that this nation devotes to research, and our institutions and approaches to research.

HUMAN RESOURCE BASE

Issues

Our human resource base – a well-educated and trained workforce – is a prerequisite to maintaining our competitive position in the world and our economic and social progress at home. The economy of tomorrow, even more than today, will require a workforce skilled in the sciences, engineering, and mathematics. The pervasive impact of science and technology on our daily lives also means that we need citizens whose level of scientific literacy enables them to participate intelligently in both private and public decisions.

Employment of scientists and engineers is increasing significantly faster than total U.S. employment, with scientists and engineers now 3.7 percent of the labor force compared to 2.4 percent 10 years ago. At the same time, the number of 22-year-olds (those most likely to receive bachelors' degrees) has begun to drop and will continue to decline into the next century.

Fewer U.S. citizens are receiving Ph.D.'s in science and engineering, and foreign students have increased significantly as a percentage of all graduate students. This is especially true in engineering, mathematics, physical sciences, and computer science. While many such students stay and work in the United States, we should not become overly dependent on foreign sources of talent.

Simultaneously, participation in science and engineering careers by U.S. minorities and women is far below their proportions in the population. These groups represent the largest potential untapped sources of science and engineering talent in the nation. Despite recent efforts toward change, enrollments of Blacks in college, especially in science and engineering fields, show serious reductions. Blacks and Hispanics in graduate science and engineering degree programs also show level or declining participation. Women earn about 5 percent of Ph.D.'s in engineering and 26 percent of doctoral degrees in the sciences. Although considerably improved from a decade ago, these participation rates are leveling off.

Nor do these numbers tell the whole story: quality and appropriateness of skills are also crucial. While the quality of our graduates remains high, indicators of future problems abound. Achievements of American elementary and secondary school students on standardized science and mathematics tests are low – both in comparison with a decade ago and relative to other industrialized countries.

Actions

We must compensate for the decreasing college-age population by drawing more students into science and engineering majors, especially groups underrepresented in science and technology. Among the steps needed is improvement of the reward system for science and engineering careers.

Increasing the representation of minorities and women in science and engineering is a goal we should seek as a matter of equity as well as necessity. These segments of society contain untapped reservoirs of talent in science and technology.

State and local governments are acting to remedy weaknesses in such areas as curricula and training/incentives for elementary and secondary education teachers. The Federal Government also has a role to play in selected activities with high impact that can help local communities improve their schools.

The National Science Foundation's own role is that of a catalyst for activities of state and local governments and educational institutions. NSF programs are directed to all levels of education and all citizens, with special attention to minorities, women, and the disabled.

At the *elementary and secondary* levels, NSF helps provide a linkage between the scientific community and teachers. The Foundation supports activities such as the development and dissemination of model instructional materials, assessments of education in science and mathematics, and efforts to improve teacher capabilities and performance.

NSF is increasingly active at the *undergraduate level,* using leadership and program support to strengthen this key segment of the educational pipeline. A major NSF goal is to stimulate further involvement of academic scientists and their institutions, the states, the private sector, and other federal agencies in undergraduate science and engineering education.

Finally, NSF has a unique role in *graduate education* in science and engineering because of the link between graduate education and research. This traditional role is inherent in NSF's traditional support of research and is also exemplified in graduate fellowships, for which NSF has increased funding in recent years.

FINANCIAL RESOURCES

Issues

The United States makes by far the largest investment in R&D of any western country. However, in relation to our overall economy, we invest about the same proportion of GNP as other major western industrialized countries. R&D growth rates in Japan and West Germany, however, have been rising faster than those of the United States.

A further breakdown of R&D into defense and civilian R&D is especially revealing. U.S. civilian R&D as a percentage of GNP continues to lag far behind the German and Japanese rates, and the difference is growing. In the United States, just under half of all R&D is supported by the Federal Government, and nearly 70 percent of this is for military R&D, up from less than 50 percent a decade ago. More than 95 percent of military R&D is for applied research and development; basic research has shrunk significantly and is now a very small component. While defense R&D programs contribute to the tech-

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nology base for the civilian sector, the converse is also true. We must assure that, in creating a strong national defense, we do not draw resources from the civilian sector to an extent that damages our capability for productivity growth and competition in world markets.

The Federal budget for science and technology is developed jointly by the Administration and Congress in an environment of many competing claims. In the last few years, macroeconomic problems have severely constrained the resources available to science and engineering. The hard choices that were collectively made to meet these immediate problems will have long-term negative repercussions for technology and economic competitiveness. The Administration's Fiscal Year 1989 Budget Request for NSF, which puts the Foundation back on the track of a doubled budget by 1993, is an important step in rectifying this situation.

Actions

Appropriate Federal roles in supporting a strong science and technology capability are diverse. The Federal Government must provide a positive climate for technological innovation and productivity growth, which in turn encourages private sector R&D investment. The private sector, as in the past, should be expected to continue its own investments in research and development; the government should not displace private sector generation of technology.

The Federal Government provides direct research and development support for its own needs, such as in defense and space. We must sustain a Federal R&D strategy balanced between the needs of the defense and civilian economies. R&D programs must provide strong support to academic institutions that ultimately supply human resources and new knowledge for all sectors.

In the civilian sector, the Federal Government provides research support as an investment in the future when there is substantial prospect for significant gain to the nation, but where the private sector is unlikely to invest adequately because of long lead times, high risk, and unrecoverable costs.

How much should we invest for this latter purpose? **The National Science Board believes the Federal Government should support enough basic research that the United States can maintain a leadership position in all important areas of science and engineering.**

This support should encompass people, equipment, and (where needed to conduct the research) facilities. Although support for people is the highest priority, needs for equipment and facilities in the nation's research institutions continue to mount. A significant factor is the nature of the research enterprise itself, which is becoming more capital intensive in its need for sophisticated and expensive instrumentation and facilities. Construction, operation, maintenance, and renovation of facilities will be growing challenges.

The Administration is committed to advancing science and technology because of their fundamental relationship to U.S. competitiveness. As part of that strategy, **the Administration has proposed to double the NSF budget by 1993. This action would help redress the balance between defense and civilian research. It would strengthen NSF's position as the lead agency in general basic science and engineering research and education within the Federal Government.**

In seeking its central role within the Federal Government, NSF, as in the past, will be guided in the research it supports by both the intrinsic merits of the fields and activities and the economic consequences of its programmatic activities.

INSTITUTIONS AND APPROACHES

The conduct of science and engineering research in the United States is undergoing great change. The boundaries of the disciplines have become hazy as more and more research questions cross traditional disciplinary lines. As science and engineering change, institutions that support and perform research will change, as will approaches to research.

Issues

An example of change is the growing importance of industry in research. In 1986 U.S. industry provided half the funds for U.S. R&D and performed 73 percent of all R&D. Industry support of its own R&D between 1975 and 1985 rose faster than Federal support for industrial R&D. Industrial R&D has been rising much faster in high-technology manufacturing and non-manufacturing industries than in other manufacturing industries. Industry also increasingly supports research in universities, although its share of total university support is modest – just over 5 percent.

There is dramatic evidence of increasing university-industry collaboration in research within the United States. More than a third of professional journal articles with industry authors are now coauthored across sectors, including universities, compared with less than a fifth a decade ago.

Another change is the increasing internationalization of scientific and engineering research. International coauthorships are burgeoning, and U.S. citation of non-U.S. literature is increasing. Exchange visits are also on the rise, though growing faster among foreign nationals than for U.S. citizens.

Actions

Federal policy should support research collaboration across sectors. While Federal investments in basic research should be concentrated in universities because they produce both research and education through a single investment, linkages between universities and industry should be supported. Mutual benefits result – transferring basic knowledge into products, processes, and services in the business sector, transferring knowledge of industrial scientific and engineering problems to university researchers, and providing a source of diversified talent for both sectors. Government policies such as tax credits and programs that require industry participation encourage companies to assist and collaborate with universities, enhancing the Federal research investment and leading to economic and social benefit.

In the international arena, given the increasing relevance of foreign scientific work to U.S. science and engineering, our scientists and engineers must be encouraged to travel, to develop foreign language skills, to communicate with their foreign peers, and to exchange visits. The United States should participate fully in international cooperative projects and develop and maintain close ties with counterparts elsewhere. The increased scale and complexity of many modern scientific projects requires facilities and operations whose costs strongly suggest the utility of international coordination, sharing and, in some cases, cooperative funding.

Cooperation in the face of international competition is not a paradox. Science advances without respect to national boundaries and is aided by open discussion.

Openness on the campuses of American colleges and universities is vital, for it is there that new research directions are frequently conceived, and there that the next generation of scientists and engineers is trained. Restrictions on openness are likely to have serious costs to science and, ultimately, to national security and economic competitiveness. Since research capabilities abroad have strengthened relative to our own, it is especially important that we have access to work by our foreign counterparts. **We must assure that our international collaborations provide mutual benefits and equitable sharing of research costs, and that they encourage openness by other countries.**

The global nature of many scientific problems requires increased international cooperation. NSF will continue its leadership role in planning and implementing major global initiatives, such as global geosciences and environmental research in the Antarctic. The Foundation will develop a broader, more comprehensive information base for planning and managing effective international cooperative programs.

NSF will also take an active role in developing and nurturing the research effort and the organization of research in the United States. It will be an innovator, not only in the science and engineering it supports but also in modes of research support.

CONCLUSION

Science and engineering in the United States are at a watershed. At no time has there been such dynamic change as today. How we take advantage of it will determine our national security, social well-being, and economic competitiveness for years to come.

International competition is much stronger than in the past and will continue to increase. The competition we face goes beyond trade and economics to scientific and engineering capabilities and even to the human resources needed in a technological society. If the United States is to be competitive in international markets, we will need an even more robust science and engineering capability than we have had in the past. Strength in basic research, while not sufficient by itself to generate a competitive advantage or growth in productivity, is a necessary ingredient. It must also be accompanied by an educated populace, creative industrial managers, and supportive macro-economic policies.

NSF's roles are to:

(1) support advances in science and engineering that lie beyond the horizons of most companies;

(2) encourage transfer of those research results;

(3) encourage high quality education in science and engineering at both graduate and undergraduate levels;

(4) help to improve the teaching of mathematics and science in primary and secondary schools; and

(5) help to encourage and prepare our young people to become scientifically literate citizens and to participate in science and engineering as researchers or practitioners.

There is much strength in U.S. science and technology, and much that needs to be done. As members of the National Science Board, we are confident that with the continued support of the Administration and the participation of all levels of government and all sectors of the economy, the United States will continue and strengthen a resurgence of economic progress. **The case for investing in talent and knowledge as the basis for a strong economy is compelling—an issue around which all individuals and interest groups can join.**