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ABSTRACT

Sustained investment in science and engineering research and education in universities in the United States is advocated as a means of progressing economically. Information related to economic advancement is provided through summaries of recent trends in research, education, and economics. Ideas and data are reviewed in reference to: (1) the need for government supported research (highlighting the intellectual, pragmatic, and economic goals of research); (2) the need for economic competitiveness (assessing the status and trends of economic productivity); and (3) the quantity of research (examining efforts in supporting research, educating new scientists and engineers, and investing in research facilities and equipment). Basic research and education in science and engineering are viewed as a responsibilty of the federal government and are offered as the best single way to provide jobs and the national wealth for the future. (ML)

BASIC RESEARCH:

The Key to Economic Competitiveness

by
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Basic Research: The Key to Economic Competitiveness

> On the wisdom with which we bring science to bear against the problems of the coming years depends in large measure our future as a nation.
>
> Vannevar Bush
> *Science—The Endless Frontier*
> July 1945

More than forty years ago Vannevar Bush concluded his famous report to the President with these words. That report noted the contributions that science had made to winning World War II, and argued that the economic battles that lay ahead in 1945 would also require a major effort in research and development if the United States were to prosper.

Science—The Endless Frontier made the case for continuing the wartime effort in basic research through a new agency, and the result was the creation of the National Science Foundation in 1950. The mission of the Foundation was to support basic research and education in the sciences and engineering. The belief was that new knowledge and new researchers would strengthen the nation both militarily and economically.

The case for a strong national effort in research and education in the basic sciences and engineering is as strong today as it was in 1945. We continue to need a strong defense, and we face economic competition to a degree not imaginable in 1945. The need to strengthen our science and engineering base—the collection of people, facilities, and equipment that makes basic research possible—may be even greater today than it was in 1945, because in the past two decades the base has deteriorated markedly.

This booklet summarizes recent trends in research, education, and economics. It makes the case once again that the nation cannot prosper without sustained investment in science and engineering research and education in our universities.

Why Should the Government Support Research?

The federal government supports research in pursuit of three goals.

- Intrinsic intellectual value;
- To accomplish a specific government mission such as defense or health;
- To make the nation's economy more competitive.

The Foundation has always been dedicated to the first goal -intrinsic intellectual value. The nation benefits from significant advances in any field of science and engineering, although the specifics can never be foreseen. The Foundation has always sought to support the most promising work in every field It will continue to seek excellence in this way.

The second goal accounts for a large proportion of federal support for research and development (R and D). This research may be quite basic in character, but it is driven by the need to accomplish particular missions. This makes the research the proper concern of the agency with the mission responsibility.

The third goal is to perform research that will ensure the nation's economic competitiveness. The need is to do the basic research, and to train the people, that will enable American industry to develop and market products successfully in the international marketplace. This is an area that has had too little attention in recent decades, and one in which the National Science Foundation has much to offer.

The Need for Economic Competitiveness

The world has become a much more competitive place in recent years. The United States was in an economically dominant position at the end of World War II. We had the most advanced technology, and we had the manufacturing and marketing resources to dominate international trade.

That favorable position, however, is gone. The developed nations rebuilt their industry after the war and greatly increased their investment in research and education. And in recent years a number of the developing countries have also become serious competitors.

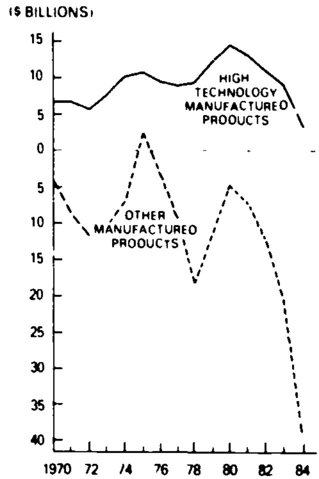
Consider these facts:

Fig. 1 • Our trade balance is overwhelmingly negative, and becoming more so. Even the advantage in the high-technology industries that we once took for granted has virtually disappeared.

Fig. 2 • To be economically competitive we must have high productivity. But in recent years our productivity increases have averaged a scant 0.3% annually. Our competitors have done five to fifteen times as well.

Figure 1.

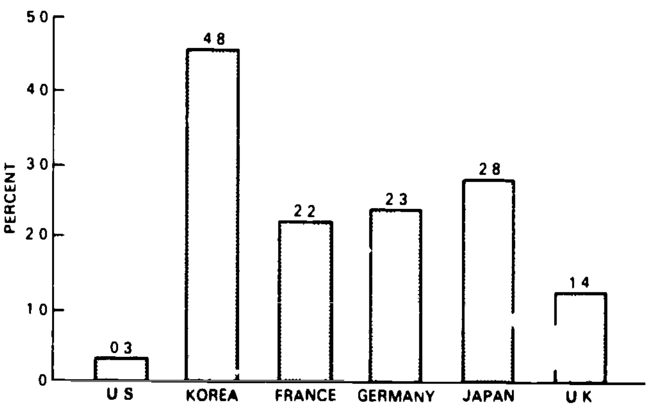
U.S. TRADE BALANCE IN HIGH-TECHNOLOGY AND OTHER MANUFACTURED PRODUCT GROUPS, IN CONSTANT DOLLARS



Source SCIENCE INDICATORS THE 1985 REPORT National Science Board National Science Foundation 1986

Figure 2.

AVERAGE ANNUAL PRODUCTIVITY GAINS, 1973-83

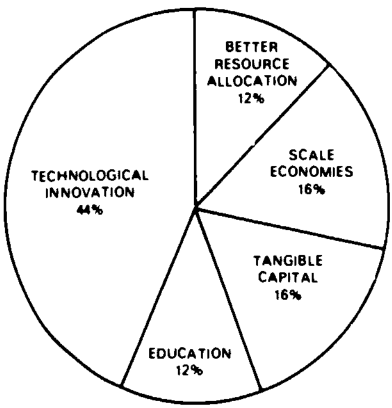


Source U S Department of Labor Bureau of Labor Statistics May 1984

Fig. 3 • Since World War II, new technology has been responsible for nearly half of all productivity increases - more than those due to more capital, more education, or any other single factor.

Figure 3.

CONTRIBUTORS TO U.S. PRODUCTIVITY INCREASES



Source Edward Denison Accounting for United States Economic Growth 1929 69 Brookings Institution 1964

In recent years the markets that we have to sell our products in have become international; we no longer have the luxury of a large domestic market that our own industries dominate. This is true for both high- and low-technology industries, both computers and shoes. Success in this situation depends on having advanced products, and also competitive pricing, which depends on production efficiency.

Our competitiveness can be improved by developing automated production systems that will give our industries an important advantage. Doing it this way - by improving our own performance through research - is far preferable to relying on trade barriers or other protectionist measures.

Are We Doing Enough Research?

Any society that wishes to remain competitive in the modern world must do three things:

- It must support basic research adequately;
- It must educate enough new scientists and engineers; and
- It must invest sufficiently in research facilities and equipment.

Our record in all three areas is less than it should be. Consider first our level of effort in R and D:

Fig. 4 • The United States has not invested in R and D in recent decades at the rate that sustained growth in a modern society requires. We have slipped from the position of leadership that we held twenty years ago, while our competitors have been pushing ahead in an effort to challenge and surpass us in key technological areas.

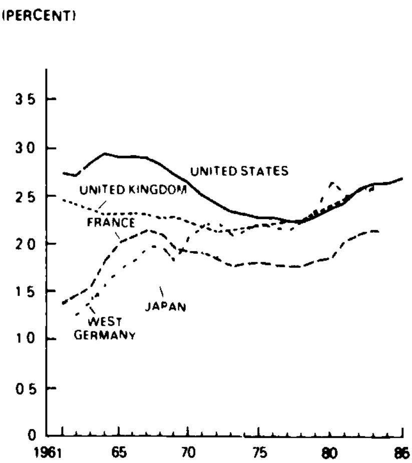
Fig. 5 • Furthermore, the proportion of U.S. federal research support that goes for military purposes is high and rising.

At one time defense oriented research had major positive effects on the civilian economy, because the military was interested in technologies - such as computers, semiconductors, nuclear power, and rocketry - that were more advanced than anything in the civilian sector. This is no longer true to the same extent, however, because in most cases civilian technology is now more advanced than that used by the military.

Fig 6 • When military research is eliminated from the comparison, our effort in R and D is significantly less, as a fraction of GNP, than the effort made in Japan and Germany.

Figure 4.

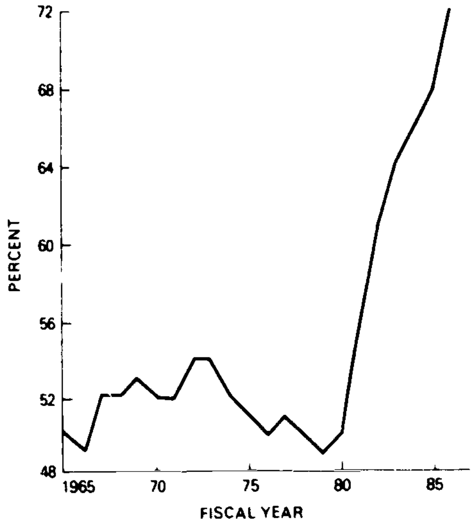
NATIONAL EXPENDITURES FOR PERFORMANCE OF RESEARCH AND DEVELOPMENT AS PERCENT OF GROSS NATIONAL PRODUCT BY COUNTRY



Source SCIENCE INDICATORS THE 1985 REPORT National Science Board National Science Foundation 1986

Figure 5.

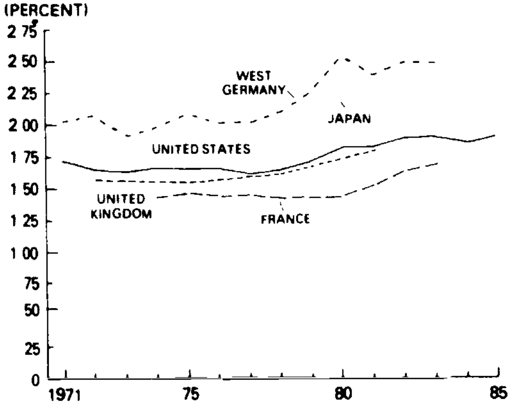
MILITARY R&D AS A PROPORTION OF ALL FEDERAL R&D



Source Office of Management and Budget Special Analysis K 1985

Figure 6.

ESTIMATED RATIOS OF NON-DEFENSE R&D EXPENDITURES TO GROSS NATIONAL PRODUCT (GNP) FOR SELECTED COUNTRIES



Source SCIENCE INDICATORS THE 1985 REPORT National Science Board National Science Foundation 1986

Fig 7 • An encouraging trend, however, has been the increasing fraction of federal support for *domestic* R and D that is going for basic research. Development expenditures are, quite properly, being left to industry.

The second area of concern is people. The research training pipeline is long, from high school through graduate school, and its size cannot be increased rapidly There must be a steady flow of young people through this pipeline if our economy is not to be starved of technical advances.

Because of the length of the pipeline, it is long-term trends that count.

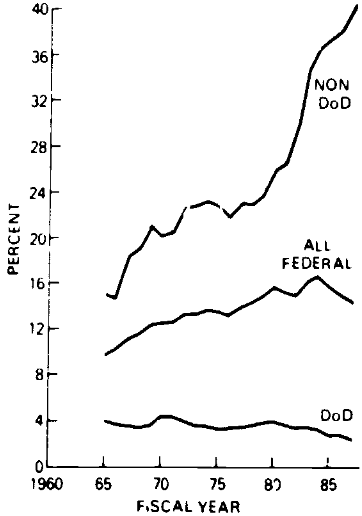
Fig. 8 • Twenty years ago the United States had far more scientists and engineers per capita than any of our competitors. Today that is no longer the case.

Fig. 9 • The proportion of our young people who are attracted to programs in science and engineering reached a peak in the early 1970's, and has since declined.

Fig 10 • The numbers of students in the appropriate age brackets will decline from now through the mid-1990's. Even if we could continue to attract students at the 1983 rate, this decline means that we would train almost 700,000 fewer graduates in these fields in the next twenty years.

Figure 7.

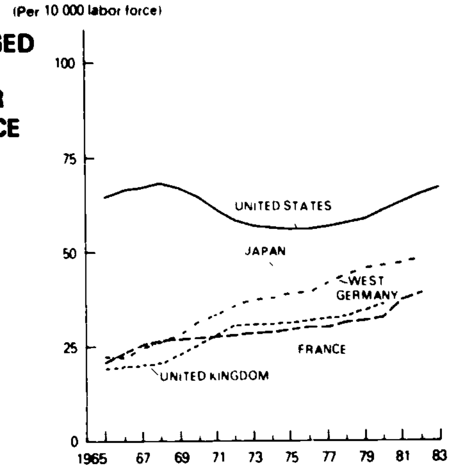
BASIC RESEARCH AS A PROPORTION OF ALL FEDERAL R&D, BY CATEGORY



Source Office of Management and Budget Special Analysis K 1985

Figure 8.

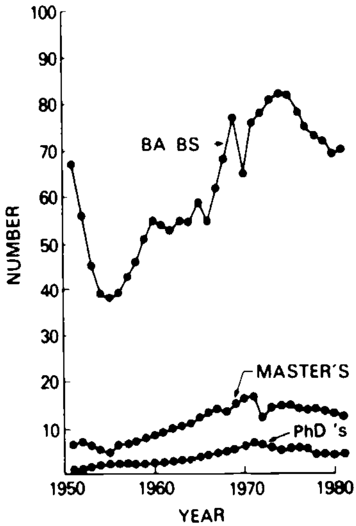
SCIENTISTS AND ENGINEERS ENGAGED IN RESEARCH AND DEVELOPMENT PER 10,000 LABOR FORCE POPULATION BY COUNTRY



Source SCIENCE INDICATORS THE 1985 REPORT National Science Board National Science Foundation 1986

Figure 9

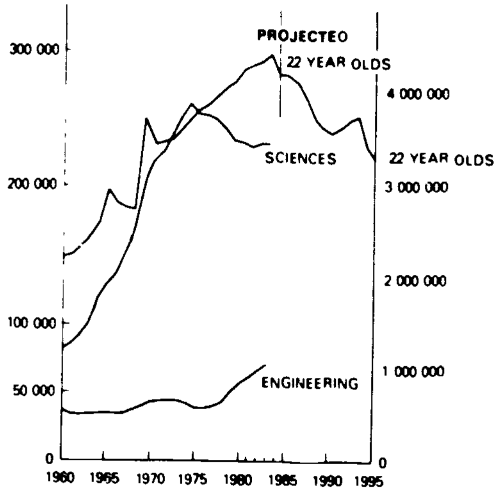
SCIENCE/ENGINEERING DEGREES PER THOUSAND IN APPROPRIATE AGE COHORT, 1950-1981



Source National Science Foundation (extrapolated from data provided by Science Resources Studies division 1985

Figure 10.

S/E BACHELOR'S DEGREES AND 22-YEAR-OLD POPULATION



Source: National Center for Education Statistics and Census Bureau data 1985

Fig 11 • With fewer American citizens electing technical fields, we are increasingly dependent on foreign nationals in some of the most important specialties. In recent years more than half of our new engineering PhD's have been foreign nationals. So have a large and rising proportion of mathematicians and physicists - and these are the core disciplines of a technological society.

Accepting foreign students is an American tradition that we must continue, in part because science and scientists are a uniquely good communication link in a troubled world. But it would be a serious mistake to rely too *heavily* on foreign sources for one of our most valuable assets for the future: scientific and engineering talent. Recruiting more of our own women and minorities into science and engineering careers is a good place to start.

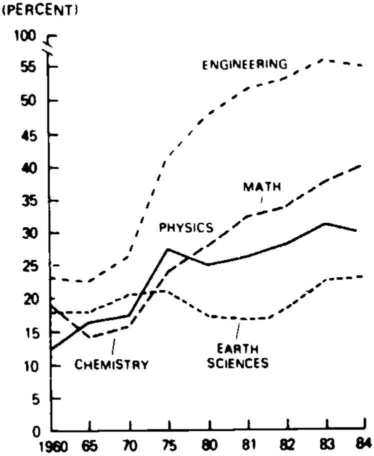
Investment in facilities and equipment is the third requirement for a technologically healthy economy. The United States has the best-developed university system in the world, and extensive facilities in government labs and in industry. Industry has kept pace with needed investment in new facilities and equipment. Government laboratories vary widely. But universities have a serious problem of obsolescence.

Fig. 12 • In the past twenty years federal investment in university research plant (facilities, land, equipment, etc.) has declined in real terms by 95%.

Figure 11.

DOCTORAL DEGREES AWARDED TO FOREIGN STUDENTS AS A PERCENT OF ALL DOCTORAL DEGREES FROM U.S. UNIVERSITIES, BY FIELD

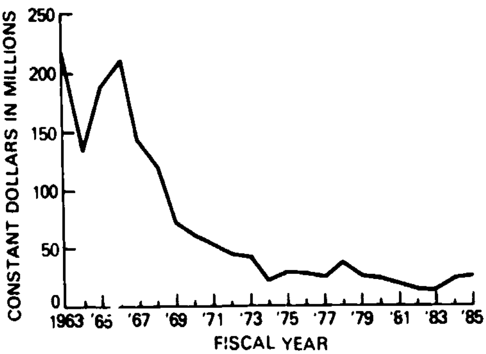
ENGINEERING, MATHEMATICS, AND PHYSICAL SCIENCES



Source SCIENCE INDICATORS THE 1985 REPORT National Science Board National Science Foundation 1986

Figure 12.

FEDERAL OBLIGATIONS FOR R&D PLANT TO UNIVERSITIES AND COLLEGES



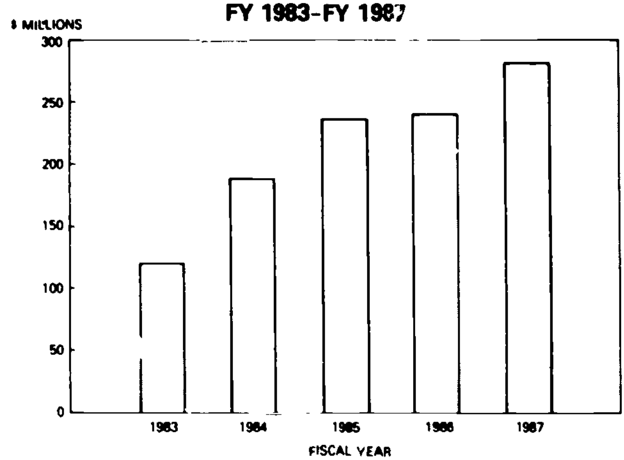
Source National Science Foundation Division of Science Resources Studies 1985

In response to a growing understanding of the need, federal investment in research equipment began to rise significantly in 1984, when it totalled about $335 million, or 6.2% of total federal R and D support to universities.

Fig. 13 • The National Science Foundation devotes a large and increasing proportion of its resources to research facilities and equipment. In 1987 it will spend almost 17% of its total budget for these purposes. Other agencies are also devoting an increasing fraction of their resources to these purposes - but the total is far from adequate to meet the need.

Figure 13.

INSTRUMENTATION FY 1983-FY 1987



Source National Science Foundation Office of Budget Audit and Control 1986

Conclusion

While industry and state governments are deeply involved, basic research and education in science and engineering is a well-established responsibility of the federal government. Basic research produces knowledge that is available to all, not just the organization that pays for the research. In many fields it is also too expensive for any single company or state government to sponsor. Thus the nation cannot rely on industry and the states to fund basic research adequately.

Investment in science and engineering research has been the source of much of our economic progress over the past four decades. It continues to be the best single way that we can provide the jobs and national wealth that we must have in decades to come.

Our science and engineering base, however, needs renewed attention. In the past two decades we have not kept up with the need to make steady investments in people, equipment, and facilities. As a result, close inspection reveals many strains and deficiencies. In the modern world that we live and compete in, such inattention to our real needs is fraught with danger.

We must meet the challenge of international economic competition in the decades ahead. Science and technology can provide the means to do it, but only if we find the resources to strengthen our effort markedly. The most basic considerations of national welfare demand that we do no less.

The National Science Foundation has TDD (Telephonic Device for the Deaf) capability which enables individuals with hearing impairment to communicate with the Division of Personnel and Management for information relating to NSF programs, employment, or general information. This number is (202) 357-7492.