Revitalizing Science
In the
Department of Energy

Science and Engineering are Paramount to the U.S.

- The nation faces unprecedented challenges to its security, economy, environment, technological leadership and future energy independence.
- For over 50 years, half of U.S. economic growth has come from prior investment in science and technological innovation.
- Future U.S. global leadership and technological capabilities will flow from our investments in research in science and engineering.
- The Federal government is the leading source of national investment in research across all fields of science and engineering.

Strengthened Investment in Science and Engineering is required to Ensure Continued U.S. Scientific Leadership

- DOE is the primary source of federal investment in the physical sciences, second in computer science and mathematics, and third in engineering.
- The nation's scientific leadership is threatened by several trends:
  - The nation's research portfolio is weakened because investment for physical sciences and engineering is stagnant and, in many areas, declining, resulting in severe imbalances among fields of science that build upon one another.
  - U.S. student enrollments and degrees awarded in the physical sciences and engineering are declining.
  - Workforce talent pools are shrinking.
  - DOE's world-class research facilities are seriously underutilized.
  - U.S. intellectual leadership faces unprecedented international competition.

Critical Initiative to Restore DOE Science

- A special five-year initiative to revitalize DOE science is required.
- In FY 2003 invest a targeted $300 million in DOE research infrastructure:
  - $100 million to strengthen research and education in the physical sciences and engineering.
  - $100 million to increase utilization of DOE's world class research facilities.
  - $50 million to develop the next generation of scientific research tools.
  - $50 million to advance research and innovation specifically in energy.
- Make equal incremental investments in DOE research infrastructure annually for at least the next five years.

Revitalizing Science in the Department of Energy

The Value of Investing in Science and Engineering

At the beginning of the 21st Century, the United States stands as the world's most powerful and wealthy nation. Fully half of the growth of the U.S. economy in the last fifty years was due to the federal investment in scientific and technological innovation, much of which flowed from our nation's research universities and national laboratories. *"It is no accident that our country's most productive and competitive industries are those that benefited from sustained Federal investments in R&D – computers and communications, semiconductors, biotechnology, aerospace, environmental technologies, energy efficiency."*

-- John H. Marburger III, Presidential Science Advisor Nominee, *Senate Confirmation Hearing, Senate Committee on Commerce, Science and Transportation,* October 9, 2001

The fruits of federally funded research in the physical sciences (sciences that investigate the properties of energy and non-living matter, e.g., physics, chemistry, astronomy, and geology) and engineering provide the underpinnings of our national security, technology-based economy, fast and efficient means of communication, unmatched health care system in the world, and quality of life. Recent discoveries resulting directly from research investments in the U.S. Department of Energy (DOE) include the Nobel Prize-winning discovery of new forms of carbon, non-invasive detection of cancers and other diseases, improved computer models for understanding global climate change, and new insights on the fundamental nature of matter and energy. The Office of Science also played a seminal and critical role in the sequencing of the Human Genome.

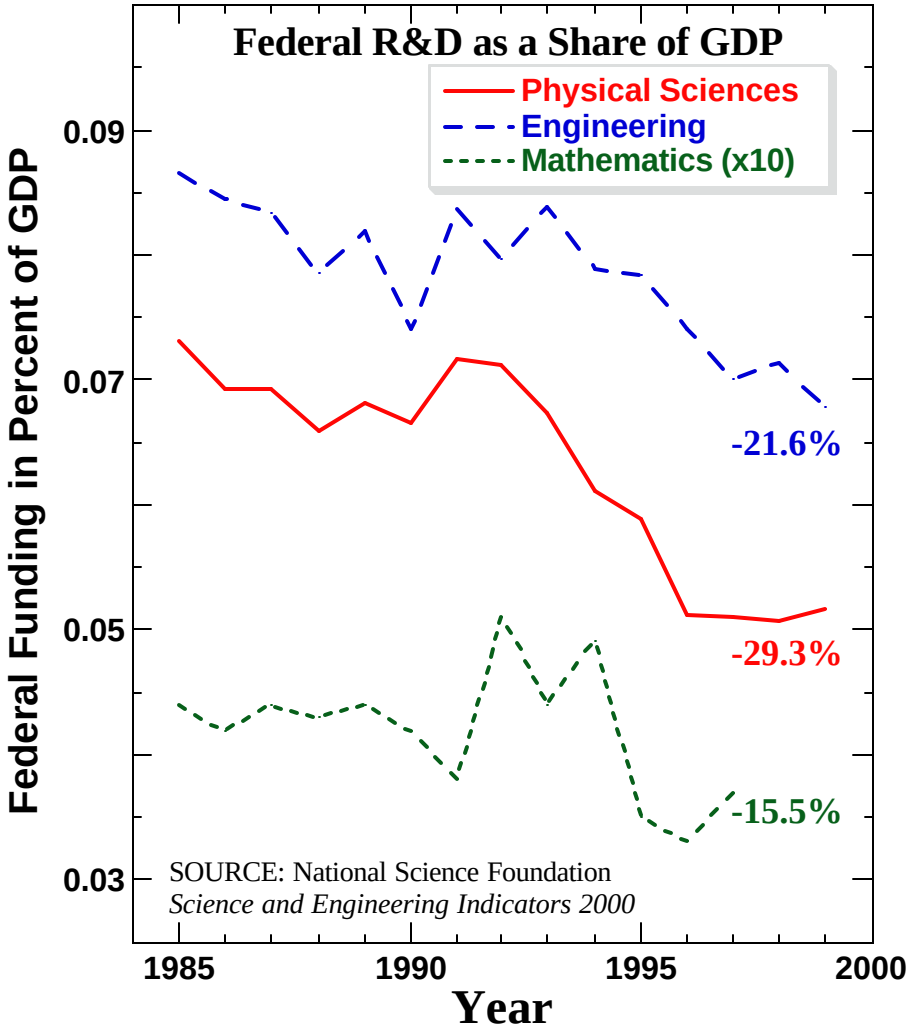
More broadly, the Internet, laser surgery, global positioning systems (GPS), fiber optics, and magnetic resonance imaging (MRI) are just a few of the transforming technologies initiated by federal investment in physical sciences and engineering research. If we are to meet the vital security, energy, and environment challenges facing the nation today, federal investment in these fields must be strengthened and the crucial role of DOE in science must be revitalized.

A Growing Weakness in the U. S. Research Investment Portfolio

The nation's investment portfolio in research is under significant stress due to declines in investment in the physical and engineering sciences. Although investment in medical and life sciences has grown steadily and significantly, equally important investment in research in the physical sciences and engineering – the kinds of research supported by the U.S. Department of Energy -- has remained stagnant or declined. Now, as the nation relies ever more heavily on innovations stimulated by science and engineering research, federal research investments are falling significantly behind the growth of the U.S. economy (Figure 1).

Lagging investment in the physical sciences and engineering fields is partly attributable to lack of real growth in the science budget of the Department of Energy and the other departments and agencies that traditionally have served as the primary sources of support for these disciplines... Funds for the Energy Department's research and development – including the national laboratories and weapons research programs – has declined in constant dollars from $11.2 billion in 1980 to $7.7 billion in 2001 (AAAS, based on OMB and agency R&D Budget Data). At the same time other agencies that also support these fields - such as DOD - have seen their science budgets decline. While investments in some agencies, such as the NIH and NSF, have increased, for the most part, these increases have not gone to support physical sciences and engineering (National Research Council, "*Trends in Federal Support of Research and Graduate Education*," 2001).

Figure 1



Under Investment Threatens our National Prosperity and Security

The nation's continued failure to invest strongly in the physical sciences and engineering will hinder economic growth, weaken national security, and limit advances in energy production, environmental protection, information technology, and medical technology.

Economic Growth

"The 21st century economy will continue to depend on scientific innovation… Technological innovation depends upon the steady flow of discoveries and trained workers generated by federal science investments in universities and national laboratories… Congress must increase the federal investment in science."

--Dr Allan Bromley, former Science Advisor to President George H.W. Bush

Industry leaders agree:

"Sustained investments in scientific and engineering research since World War II contributed significantly to America's prosperity. The need to maintain a leadership position looms larger than ever in a knowledge-driven world economy. The consensus surrounding the importance of funding basic research, however, began to weaken during the economic boom of the 1990s. Federal support—the mainstay of long-term frontier research—declined as a share of the nation's research investment. The research portfolio became increasingly unbalanced by discipline. And, the pool of American scientists and engineers shrank overall. Laboratory facilities suffered from the lack of adequate funding for modernization. These trends must be reversed if U.S. technological preeminence is to be assured."

-- Raymond V. Gilmartin, Chairman, President and CEO, Merck & Company, Inc.

-- F. Duane Ackerman, Chairman and CEO, BellSouth Corporation

-- Jack Sheinkman, Vice Chairman, Amalgamated Bank of New York

Council on Competitiveness, "Chairmen's Remarks, U.S. Competitiveness 2001:Strengths, Vulnerabilities and Long-Term Priorities," 2001

National Security

Our future national security is at stake.

"Americans are living off the economic and security benefits of the last three generations' investment in science and education, but we are now consuming capital. Our systems of basic scientific research and education are in serious crisis, while other countries are redoubling their efforts… In this Commission's view, the inadequacies of our systems of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine."

"The scale and nature of the ongoing revolution in science and technology, and what this implies for the quality of human capital in the 21st century, pose critical national security challenges for the United States. Second only to a weapon of mass destruction detonating in an American city, we can think of nothing more dangerous than a failure to manage properly science, technology, and education for the common good over the next quarter century."

-- U.S. Commission on National Security/21st Century, "Road Map for National Security, Imperative for Change," 2001

The national security of the United States has been greatly enhanced by past investments in DOE science. One field, nuclear technology, developed by the Department of Energy, has made our lives safer on a daily basis. Examples range from sophisticated scanning systems that use penetrating radiation (neutrons or energetic photons) to detect bombs or contraband to highly sensitive isotope detection techniques used for arms control and nonproliferation verification. Closer to our homes are the simple smoke detectors that sense smoke by detecting changes in the ionization of air.

In the future, nuclear techniques hold great promise for providing new and sophisticated security tools for the detection of explosives and narcotics. The Department of Energy also is currently supporting research to develop fail proof biological and chemical agent sensors that can be placed in public places. DOE is working to advance the technology for the sensors to the point in which they will avoid false alarms that might lead to needless panic and evacuations. These and other ongoing DOE science efforts will be critical to our future homeland security efforts.

Energy and Environment

"Unless innovation to increase energy end-use and to improve energy supply technologies is both rapid and global, world energy demand is likely to soar in the next century to four times today's level, entailing higher consumer costs for energy, greater oil-import dependence, worse local and regional air pollution, more pronounced climate disruption from greenhouse gases, and bigger nuclear energy risks than today. And if the United States abdicates leadership in international cooperation on energy technology, while others forge ahead, it will cost U.S. firms dearly in their share of the multi-hundred-billion-dollar-per year global market in energy-supply technologies, most of which is and will remain overseas."

-- "Powerful Partnerships: A Synthesis of a Report by the President's Committee of Advisors on Science and Technology," August 1999

Many of the energy and efficiency technologies that we take for granted today have come from Department of Energy science programs. For example, DOE energy research is directly responsible for the present generation of nuclear power plants that supply over 20 percent of the nation's electric power. DOE research is also largely responsible for continued reductions in CO_2 emissions from fossil fuels as well as from substantial improvements in the efficiency and affordability of solar, wind, biomass conversion and other renewable energy sources. DOE research is also playing a central role in helping to create new technologies - such a fuel cells - which will eliminate harmful automobile emissions.

As global population grows and world industrialization expands, cleaner and more efficient means of energy production must be found. We must find ways to better utilize natural resources and to protect the environment as we go. As in the past, the future solutions to these problems will be based in the physical sciences and engineering.

The new technologies that must be deployed between 2020 and 2050 will come only from the research we do both today and tomorrow. Our investment choices will strongly determine future national security, energy security, energy costs, greenhouse gas emissions, oil dependence, proliferation resistance, and public-health impacts. Moreover, our future economic strength will be strongly tied to the cost and availability of energy.

Medical Technology and Health Advances

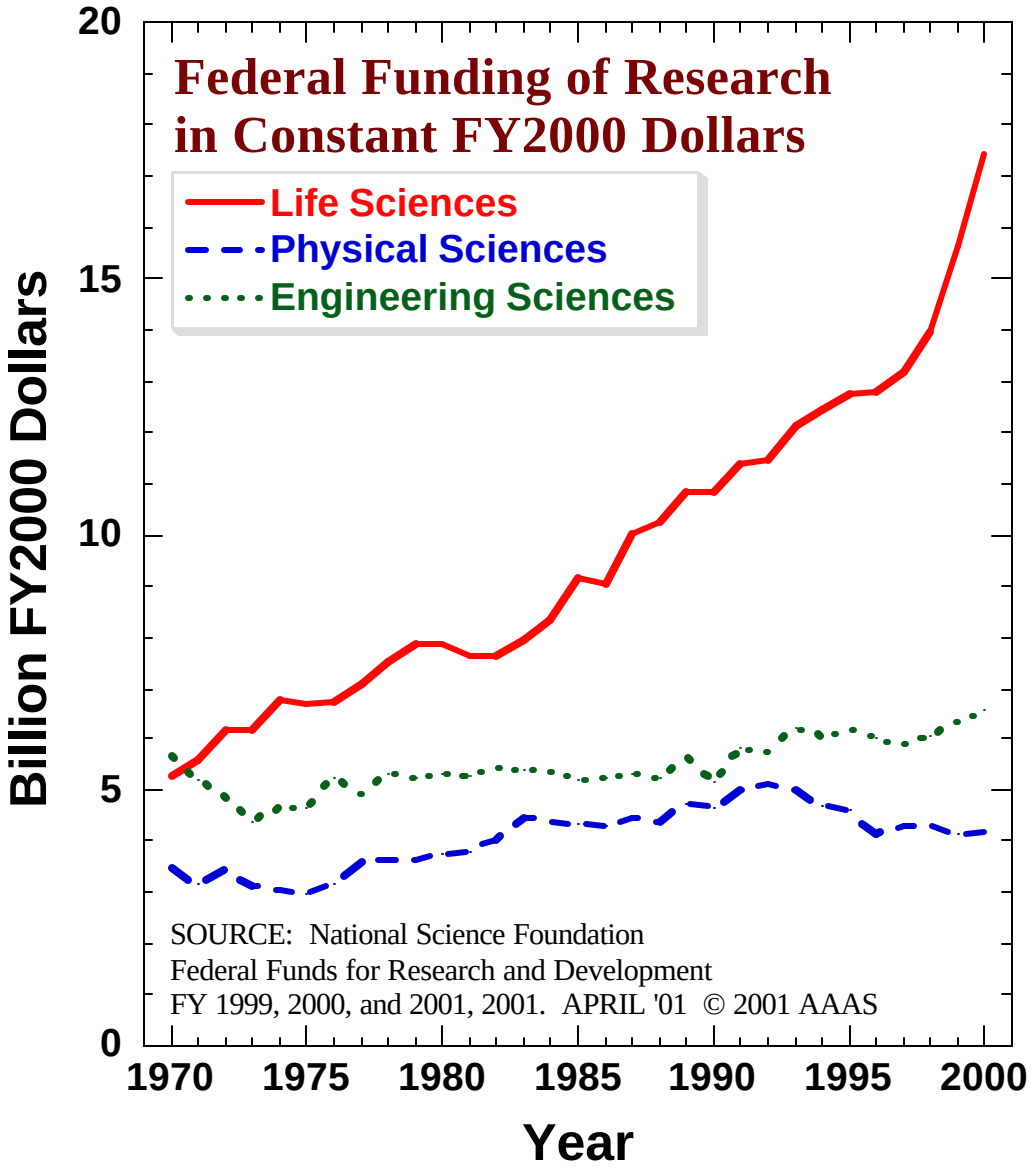
DOE research in the physical sciences and engineering has produced the knowledge that enabled major medical breakthroughs and technological advances such as diagnostic X-rays, Ultrasounds, PET Scans, and MRI's. Basic research initiated by the DOE Office of Science in 1986 culminated in the publication of a complete draft of the Human Genome sequence in February 2001. This breakthrough holds the promise of deepening the understanding of fundamental life processes and, then, treatment and cures of disease. Future medical advances and technological breakthroughs will continue to rely heavily upon the critical disciplines of science and engineering supported by the DOE.

"Our work at Pfizer in discovering and developing new medicines is critically dependent on integrating advances in many other fields from physics, chemistry, materials sciences and engineering to computer modeling and information technology. By sharing ideas from these fields, our scientists are able to create a critical intellectual mass that increases the creativity, the capacity, and the speed of innovation at Pfizer and other companies like us."

--William C. Steere, Jr., Chairman of the Board and CEO, Pfizer Inc.

The growing imbalance between biomedical fields and physical sciences and engineering research in the U.S. investment portfolio will hamper the vital connections and reliance among fields of science. In constant dollars, federal investment in the physical and engineering sciences has stagnated for the last thirty years, while that in medical and life sciences has more than tripled (Figure 2).

Figure 2



"The NIH does a magnificent job, but it does not hold all the keys to success… [The] Department of Energy's Office of Science … funds half of all research in the physical sciences and maintains the national laboratories that are central to biomedicine… Congress is not addressing with sufficient vigor the compelling needs of the other science agencies, especially … the Office of Science at the Department of Energy. This disparity in treatment undermines the balance of the sciences that is essential to progress in all spheres, including medicine."

-- Dr. Harold Varmus, Nobel Laureate in Medicine, President of Memorial Sloan-Kettering Cancer Center, former director of the National Institutes of Health

Under Investment Threatens our Nation's Preeminence in Science

Alarming trends threaten our preeminence in the physical sciences and engineering. U.S. student enrollments and workforce talent pools are declining significantly; our world-class scientific facilities are seriously underutilized; our scientific infrastructure is eroding; and the number of new and innovative ideas being produced by U.S. researchers is stagnating.

Human Resources

In 1999, the number of doctorates awarded from U.S. institutions to students in the physical sciences and engineering was the lowest in six years. At the same time, graduate school enrollments and the total number of undergraduate degrees issued in the physical sciences and engineering have been declining (Figures 3 and 4).

Figure 3

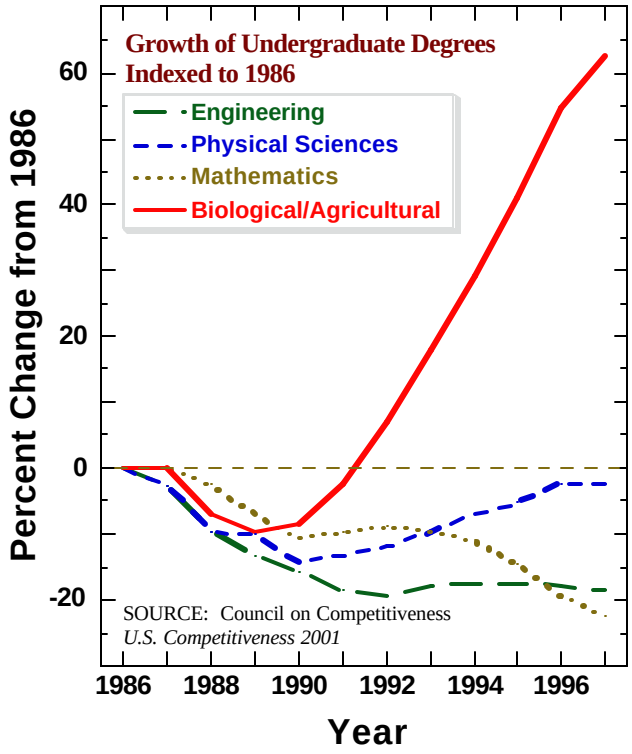
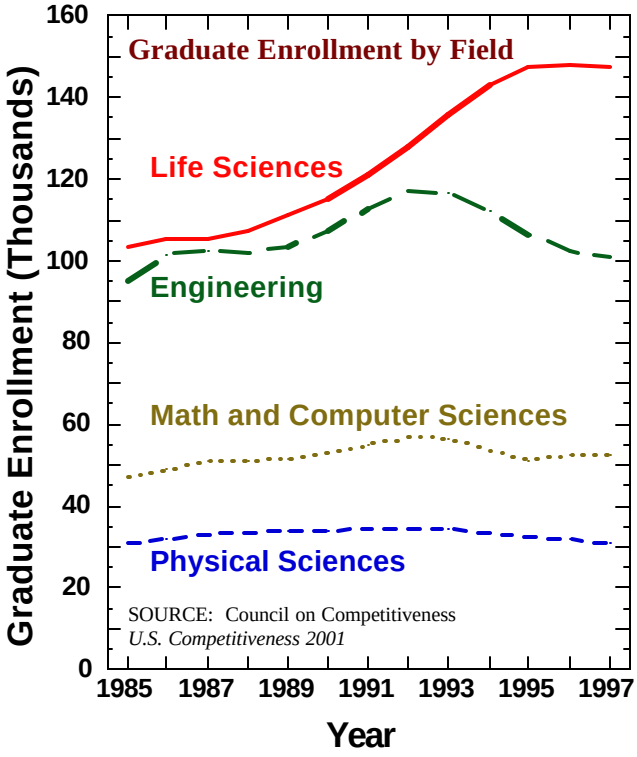


Figure 4



Curtailing investment in a research field often constricts the supply of trained people who are able to apply and exploit research advances.

"The effect of cutting research is both direct, in reducing the number of research assistant positions, and indirect, in signaling to prospective graduate students that some fields offer poor career opportunities."

-- National Research Council "Trends in Federal Support of Research and Graduate Education, " 2001

The steady decrease in degrees awarded at both undergraduate and graduate levels in the physical sciences and engineering threatens the future staffing capabilities of universities and industry, and particularly of the mission-directed national laboratories which by law are often required to hire U.S. citizens trained in these fields. Currently, only 26 percent of DOE lab scientists and engineers are under the

age of 40, compared to a national average of 40 percent in industry and other government organizations (Sandia National Laboratory, *DOE Workforce Issue Paper*, December 2000). The graying workforce at our national labs is particularly disturbing since it is often the young scientists and engineers who generate the new and creative ideas that drive innovation.

The DOE Inspector General has highlighted the emerging recruitment and retention problems facing the national labs:

> *"The Department has been unable to recruit and retain critical scientific and technical staff in a manner sufficient to meet identified mission requirements.... [I]f this trend continues, the Department could face a shortage of nearly 40 percent in these classifications within five years."*
>
> ***-- Inspector General, U.S. Department of Energy, "Audit Report: Recruitment and Retention of Scientific and Technical Personnel," July 2001***

The shortfall in skilled U.S. workers in the high tech sector has been directly reflected in the growing dependence of U.S. industry on highly educated foreign nationals who hold H-1B visas. In key natural science disciplines, such as physics and astronomy, and engineering the number of foreign graduate students now equals or exceeds the number of U.S. students enrolled in these fields (figures 5 and 6).

Figure 5

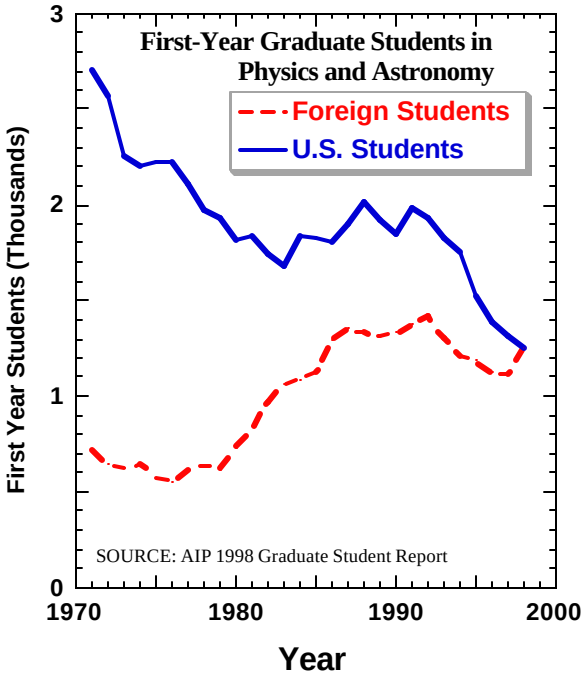
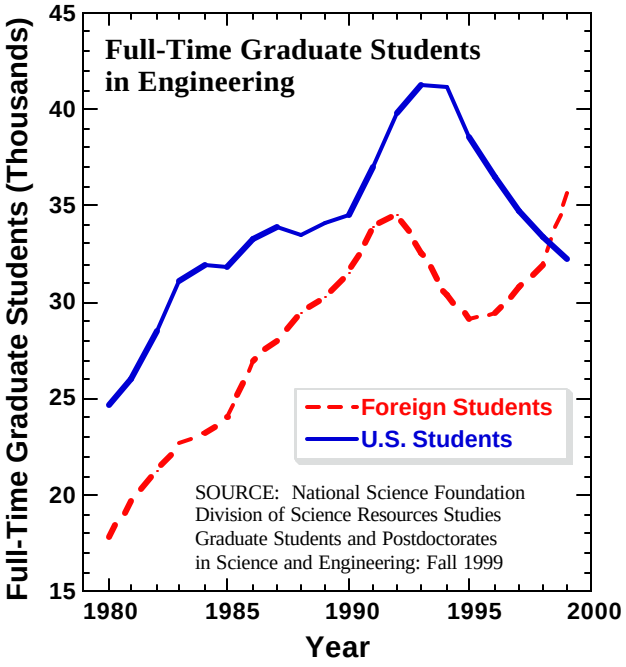


Figure 6



Scientific Facilities and Infrastructure

Most DOE scientific user facilities – large and small, all built at great expense, are operating well below their designed capacity. Many cannot meet the most urgent user demands, including those of the biological community. Still others, such as those supporting high-energy physics, are underutilized because of declining support for the individual investigators that use the facilities. This ineffective facility utilization shrinks the return on investment and discourages our brightest young students and researchers from pursuing careers in science.

Because each increment of operating funds is highly leveraged, a modest percentage increase in operating funds and support for individual investigators in certain disciplines will lead to substantial gains in scientific productivity. More effective utilization of our national facilities is sound, cost-effective science policy that ensures higher returns on investment.

Failure to fully utilize DOE facilities also threatens the national enterprise in the life sciences. For example, the Office of Science funds, operates, maintains, upgrades and supports the Nation's four synchrotron user facilities and most of the neutron facilities that enable life scientists to investigate biological structure. Over the past five years, the number of protein structures determined using DOE's synchrotron facilities has increased more than seven-fold while the number of biological users of these facilities has grown from 100 users in 1990 to 2,400 -- 40% of all users, today. DOE support for these facilities has not kept pace with inflation. In some areas, including basic structural biology, health effects, and nuclear medicine, the core budget has been drastically reduced "making it difficult to do meaningful science" (Federation of American Societies for Experimental Biology, *Federal Funding for Biomedical & Related Life Science Research FY 2002).*

Even for the important DOE human genome program -- budget reductions have occurred in each of the last two fiscal years. "*This disturbing trend will have significant and lasting ramifications for the progress of our nation's science,"* notes the Federation of American Societies for Experimental Biology (FASEB). The Federation urges a 15 percent increase in the DOE Office of Science for FY 2002 and a doubling of the Office of Science budget over the next five years.

New and Creative Ideas and Innovation

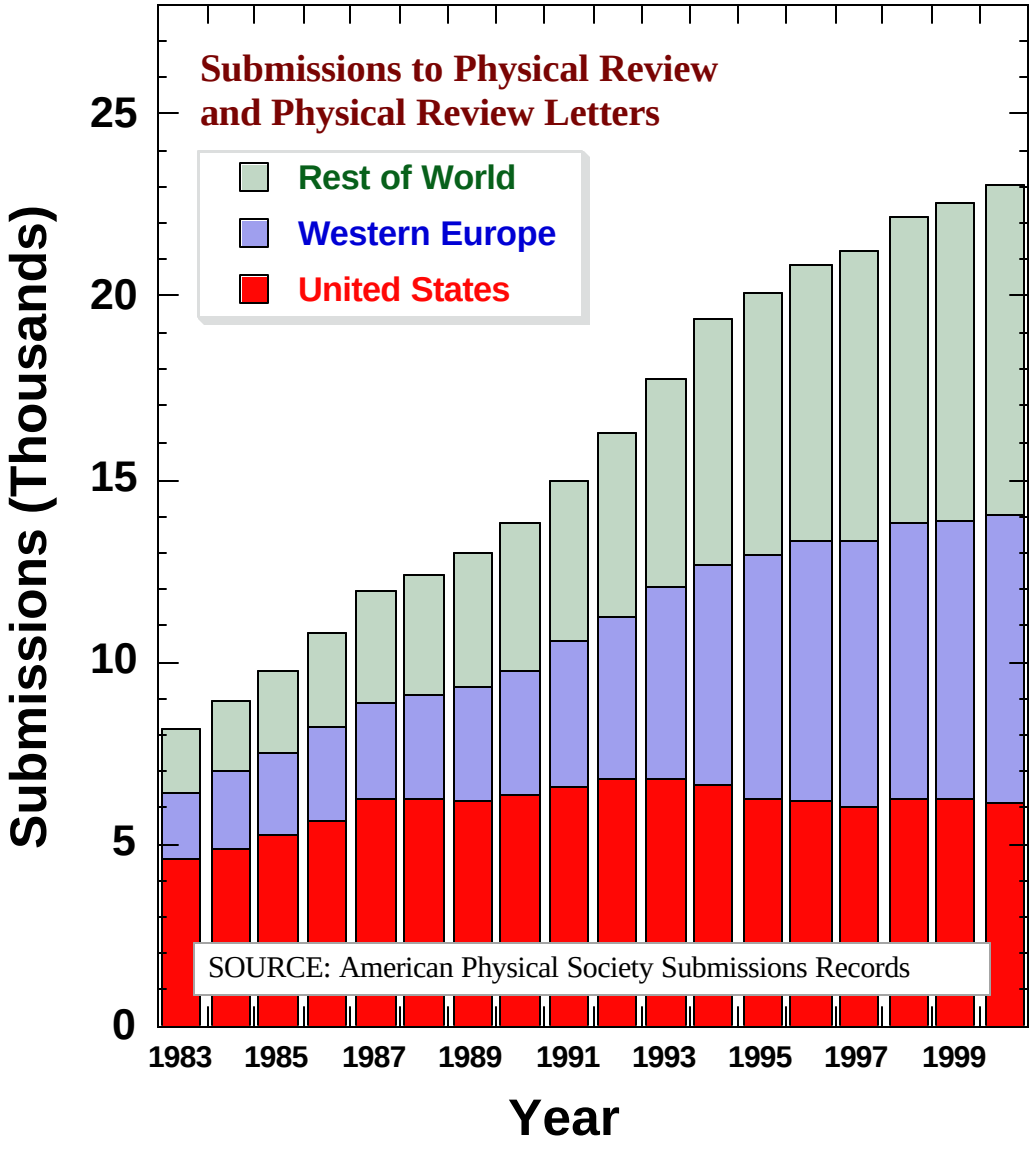
"If the United States does not invest significantly more in public research and development, it will be eclipsed by others. Recent failures in this regard may return to haunt us. The decision not to invest in a large nuclear accelerator, the Superconducting Super Collider, already means that the most significant breakthroughs in theoretical physics at least over the next decade will occur in Europe and not in the United States. The reduction of U.S. research and development in basic electronics engineering has ensured that the next generation of chip processors for manufacturing technology will come from an international consortium (U.S.-German-Dutch) rather than from the United States alone."

-- U.S. Commission on National Security/21st Century, "Road Map for National Security, Imperative for Change," 2001

One of the most significant casualties of declining federal investment in the physical sciences and engineering is the loss of U.S. intellectual leadership in essential fields because U.S. researchers account for fewer advances. While it is hard to measure increases or decreases in national "brainpower" by field, one possible measuring tool is the number of articles submitted to and published in peer reviewed scientific publications. While the U.S. has historically led the world in this area, U.S. scientific and technical publications appear to be on a downward trajectory while increasing in many other countries (Council on Competitiveness, *U.S. Competitiveness 2001*). For instance, submissions to Physical Review and Physical Review Letters from Western European researchers and those from other parts of the world combined have significantly outpaced submissions by U.S. authors in recent years (figure 7).

In some areas, choices have been made which have significantly weakened our scientific position with regard to other countries. For example, the U.S. once led the world in fusion research; that is no longer so. Similarly, our scientific position relative to other countries in High Energy Physics and Nuclear Fission Research has declined.

Figure 7

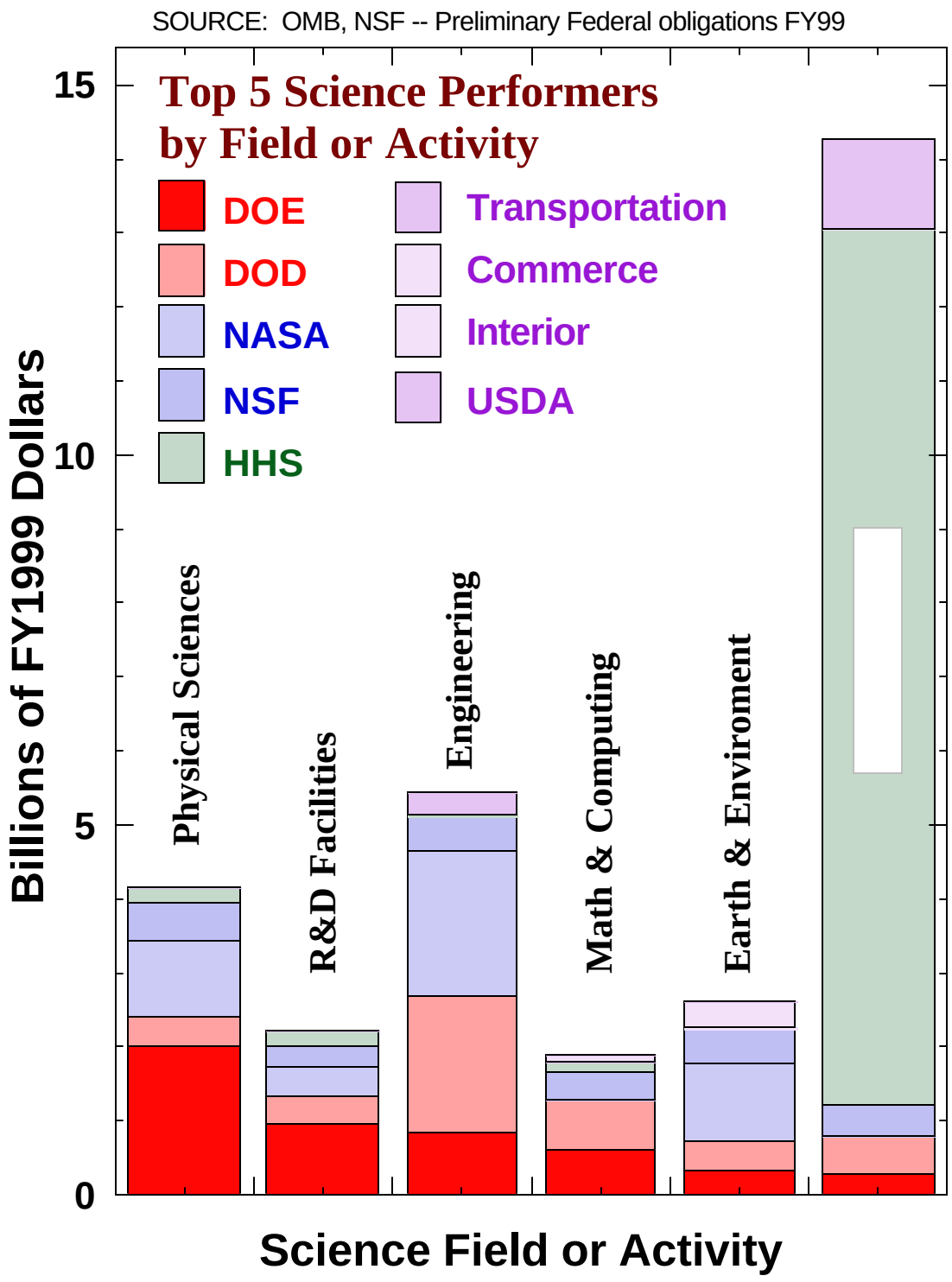


Why an Increased Investment in Department of Energy Science is Needed

DOE Plays A Unique Leadership Role in Scientific Research

The Department of Energy plays a critical role in sustaining U.S. world leadership in science. It is the leading source of federal funds for R&D facilities and for fundamental research in the physical sciences (providing over 40% of the federal investment in these disciplines). It ranks second among federal agencies in its support for computer science and mathematics behind DOD, and third for engineering research behind DOD and NASA (figure 8).

Figure 8


SOURCE: OMB, NSF -- Preliminary Federal obligations FY99
Top 5 Science Performers
by Field or Activity
DOE
DOD
NASA
NSF
HHS
Transportation
Commerce
Interior
USDA
Billions of FY1999 Dollars
15
10
5
0
Physical Sciences
R&D Facilities
Engineering
Math & Computing
Earth & Enviroment
Science Field or Activity

DOE's scientific facilities at national laboratories and universities are essential tools for U.S. researchers in a variety of fields. Since its inception as the Atomic Energy Commission, DOE has supported the work of 74 Nobel Prize winners. The DOE invests in cutting-edge research at universities and national laboratories in such diverse fields as fusion research, high energy and nuclear physics, advanced scientific computing, nanotechnology, and molecular biology.

Scientific Facilities

DOE's large-scale and specialized scientific user facilities at both the national laboratories and universities are unique and essential to the scientific programs of all other federal agencies, including the National Institutes of Health, the National Science Foundation, and the Department of Defense.

Each year over 15,000 scientists – many whose research is sponsored by the National Science Foundation and the National Institutes of Health -- conduct cutting-edge experiments using these facilities: large particle accelerators, experimental detectors, nuclear reactors, high-precision instruments, synchrotrons, massively parallel computers, high-capacity computer networks, and high-resolution microscopes. DOE's investment in these national tools sustains U.S. world leadership across most science and engineering disciplines.

Research Capabilities and Support of Core Academic Disciplines

The Office of Science directs DOE's research effort in physics, materials science, chemical science, engineering, biosciences, geosciences, life / medical science, energy and environmental sciences, mathematics and computer science. It also maintains critical national scientific capabilities not maintained by other federal agencies. DOE is the primary source of federal support for a variety of scientific areas such as ceramics, corrosion, fission engineering, combustion, catalysis, photovoltaics, superconductivity, radiation effects, plasma science, nuclear imaging, carbon cycle research, and advanced computer science. Many of these areas are specially oriented and critical to advancing DOE's national security and energy and environment missions.

Education and Training

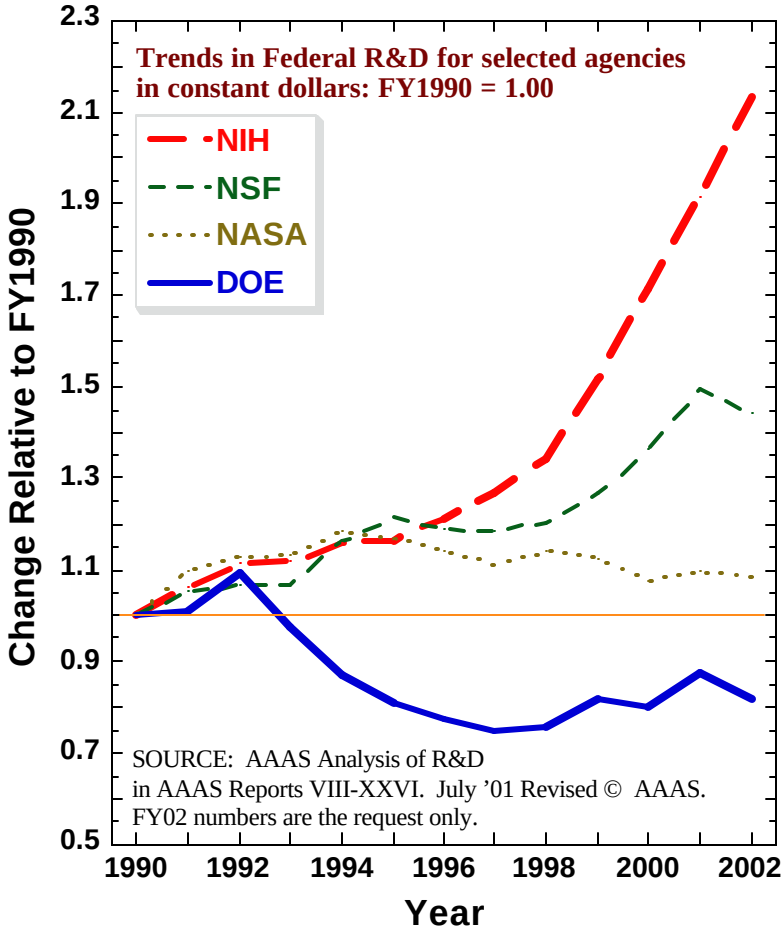
Roughly 23 percent of DOE science funds are awarded to universities. DOE supports more than 5,000 graduate students and postdoctoral fellows. Half of the scientists who use DOE user facilities, over 7000, are faculty and students from universities whose research and education depends critically upon the continued and effective operation of these facilities.

DOE also reaches out to K-12 children and their teachers to help improve children's scientific and mathematical knowledge and understanding of global energy and environmental challenges.

Funding for DOE Science has Lagged Significantly Below other Science Agencies

Despite the unique role played by the U.S. Department of Energy in our nation's scientific infrastructure, the accumulated needs have far outpaced available funding. Furthermore, DOE support has lagged seriously when compared with other federal agencies (Figure 9). Therefore, overall funding for physical sciences and engineering in the U.S. is not in balance with funding for other areas of science, and this imbalance has now reached a critical level.

Figure 9



An Initiative to Revitalize DOE Science

The DOE role in science must be revitalized and strengthened if the nation is to continue to receive the essential benefits of science and engineering research. DOE must step up to its important responsibility as the largest single U.S. investor in research in the physical sciences, third largest investor in engineering, and the third largest investor in basic research. The growing interdependence between the physical sciences and engineering, the life and biomedical sciences and other key areas of science, requires that investments in the Office of Science keep pace with the investment commitments of NIH and NSF.

To revitalize the Nation's research portfolio in the physical and engineering sciences, a new $300 million initiative is proposed for the Office of Science in FY 2003 with equal additional increments in each of the next five years:

$100 million to strengthen the base of research and education in the physical sciences and engineering at universities and national laboratories.

These funds should be targeted to achieve the following objectives:

- Rebuild lost infrastructure of research groups at universities and national laboratories by allowing them to upgrade their equipment and hire needed technical support staff;

- Address the emerging human resource crisis by creating new graduate and post-graduate research assistantships at more attractive salaries;
- Increase the size and duration of grant awards to DOE individual investigators;
- Create or upgrade university-based laboratories and equip them with cutting edge technology to attract the Nation's best minds into research careers;
- Support undergraduate and K-12 programs that encourage young people to pursue training and advanced degrees in physical science and engineering fields;
- Fund outreach programs at both universities and national laboratories that enhance the scientific literacy of the public.

$100 million to increase effective utilization of world class facilities at national laboratories and universities.

These funds should be targeted to:

- Properly operate our forefront user facilities to ensure an appropriate scientific return on recent investments. In recent years, budgetary constraints have forced many of the Nation's user facilities to operate much below their design capacity. Modest increases of 10-20 percent can double the research productivity of many forefront facilities. Increases in operating funds will be allocated on a case-by-case basis and after an in-depth review of a facility's cost-savings and efficiency measures.
- Increase the level of funding available for individual investigators and research teams wishing to conduct research using national user facilities.

$50 million to develop the next generation of scientific tools and capabilities.

These funds should be used to:

- Fund R&D and the conceptual design reports for a new generation of user facilities and equipment to ensure the long-term competitiveness of the U.S. research enterprise.

$50 million to advance research and innovation related specifically to DOE's Energy mission.

These funds should secure the following targeted objectives:

- Revitalize nuclear and fusion energy research programs at universities and national laboratories,
- Increase basic research to advance energy efficiency and renewable sources of energy,
- Modernize selected university-based research reactors,
- Address the technical, policy, and educational issues important for the Nation's energy needs,
- Evaluate and explain to the public the benefits and risks associated with reprocessing nuclear fuels to reduce or eliminate the need for safely storing nuclear waste for tens to hundreds of millennia.