Strengthen the Federal Commitment to Science and Technology

Eamon M. Kelly

During the past decade, the US experienced an explosion of benefits from long-term federal investments in science and technology. Those benefits have become increasingly visible and pervasive—from national economic growth driven by high-tech industries to science- and technology-based transformations in many areas of public and private life, including information and communication, health, and national defense.

Opportunities abound for even more remarkable advances in the future. In genomics, new possibilities have arisen for medical diagnosis and treatment and a "golden age of discovery" in plant biology. Computing will make it possible to process massive amounts of complex information at the high speeds needed for 21st-century science and engineering (see PHYSICS TODAY, February 2002, page 42). And in cosmology, innovations in instrumentation for the collection, manipulation, and detection of radiation at all wavelengths can serve as a foundation for important new communications technologies.

The contributions of science and technology to our economy and quality of life underscore the value of sustained public investment in people, ideas, instrumentation, and facilities across the frontiers of knowledge. Back in 1945, Vannevar Bush in *Science, The Endless Frontier*, argued for a federal policy to support research and education in science for the good of the nation: "Without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world." He pointed out that "the real ceiling on our productivity of new scientific knowledge and its application . . . is the number of trained scientists available."

EAMON KELLY *is a president emeritus of Tulane University in New Orleans, Louisiana, and a professor of international development at Tulane's Payson Center for International Development and Technology Transfer. He also is the immediate past chairman of the National Science Board.*

The federal government, though, has not sufficiently supported US science and engineering research and education. In its recent report, the US Commission on National Security/21st Century stated forcefully that the long-term diminution of the government's role in these areas threatens our nation's future prosperity and security.[1] And the nonprofit Council on Competitiveness reported that the US government has failed to provide an appropriate foundation for innovation, and noted a relative decline in the federal contribution to national R&D—especially significant for basic research.[2] The observed declines in graduate enrollments in physical and computer sciences and in workers employed in R&D are evidence of "a gradual weakening of the [national] science base and pool of talent," according to the council.

A cross section of spokespersons for the private and public sectors, including representatives from the US Chambers of Commerce, the Federal Reserve, Congress, and academia, have affirmed the importance of federal funding of basic research, including high-risk basic research. The National Science Board (NSB) defines high-risk basic research as long-term research that is funded primarily by the government and often relies on unique instrumentation and facilities but that offers the possibility of major breakthroughs in knowledge. Nonfederal sectors of the economy—industry, higher education, state, and nonprofit—depend on such support. High-technology industries rely on basic discoveries to fuel innovation, but industry is devoting a declining share of its financial support to long-term, high-risk research in order to maximize short-term profits. In the aggregate, high-risk research yields very high payoffs for the nation, but often requires years or decades to produce results. Most private firms cannot justify such investments.

To a significant extent, the federal government's long-term investment in science and technology has been justified: Our society is expected to be better prepared to respond to unpredictable opportunities and needs as they arise. Since September 11th, national defense, involving both military action abroad and homeland security, has created new and diverse challenges for US science and technology. Success in meeting such challenges—as well as others affecting health, prosperity, and quality of life—inevitably rests on our ability to marshal new or improved knowledge and technologies, or to deploy the existing ones in innovative ways.

Measuring the decline

How prepared are we to tackle these challenges? The NSB, in its role as adviser to the president and Congress, has highlighted over the past decade the importance of adequate federal support for basic and high-risk basic research. According to the NSB's *Science and Engineering Indicators* for 2002, during the 1990s the US maintained or improved its position, relative to other nations, in the use of new knowledge, techniques, and technologies[3] (see PHYSICS TODAY, June 2002, page 20). By the end of that decade, the US remained the leading exporter of high-technology products and knowledge-intensive service industries, such as finance and communications. The NSB, however, cautions that our advantage has been shrinking over the past two decades in three high-technology industries: aerospace, computers and office machinery, and pharmaceuticals. But during the same time period, exports did improve in the communications equipment industry.

Measures of US leadership in fundamental scientific knowledge, although positive, also show relative decline. As the NSB reported, although the US remains the largest performer of R&D worldwide as of 1998 (44% of the total for the Organisation for Economic Co-operation and Development, which has 30 member countries), capabilities of other nations are growing, and those nations are becoming more competitive. The OECD accounts for roughly 90% of the world's R&D expenditures. Non-OECD countries, especially China, account for the rest.

Growth in US scientific output can also be measured by the number of journal articles written by scientists at US institutions. The number stagnated from 1986 to 1999, whereas that of our Western European and Asian counterparts rose, according to the NSB report. Furthermore, the US portfolio is diverse but emphasizes the life sciences. Western Europe also emphasizes the life sciences, but physical sciences are more prominent there than in the US. Eastern Europe focuses on the physical sciences, whereas Asia has a near balance between physical and life sciences. With other countries emphasizing different areas of research, the US must both increase its investment in research and collaborate with other countries to retain leadership in key fields.

Achieving a balanced research portfolio is as important as the quality and quantity of research funded. Yet federal support for the physical sciences experienced little or no growth during the past decade. During the same interval, however, funding for the life sciences increased dramatically. The issue of imbalance is a concern for a range of stakeholders in US science and technology: Shares of federal research funding shifted rapidly from a relatively close 41% share for life sciences and 37% for combined physical sciences and engineering in 1990 to a wider funding gap, 47% and 30% respectively, in 2000[3] (see PHYSICS TODAY, February 2002, page 22, and April 2002, page 30). Critics of the imbalance—including former National Institutes of Health Director Harold Varmus—argue that breakthroughs in medical research rely on advances in the basic sciences for both knowledge and instrumentation that can be applied to medical research, diagnosis, and treatment. The NSB has argued the need for new mechanisms and a regular process to assess the federal research budget as a whole, and to identify gaps, overlaps, and failures to address national research priorities.[4]

The Bush administration has been sanguine about the effects of concentrating federal funding on research related to medicine and has challenged US scientific communities to provide strong arguments for higher levels of funding for other fields. It is easy to identify weaknesses in our science and engineering enterprise that support the conclusion that some disciplines are underfunded. For example, such a conclusion is inescapable when access to cutting-edge facilities increases but funding to support principal investigators at US universities declines. This is the case for nuclear physics with a recent expansion of available time at the two largest national research facilities.[5] True, the expanded availability provides greater access for foreign scientists, but US scientists and their students may have difficulty obtaining funding for their cutting-edge research—a clear example of poor coordination and insufficient support for US science. Another indication of a lack of support is the poor average award size for both NSF's basic research projects and inadequate graduate student stipends, issues only recently receiving attention after years of decline in purchasing power.

Supporting the future—students

Some simple indicators shed light on the effectiveness of federal funding for the education—primarily through research—of scientists and engineers and their future availability. The US higher education system has grown to accommodate an increasing number of people seeking degrees in science and engineering fields. At the PhD level, however, although the number of degrees rose rapidly after the mid-1980s, little growth occurred in the number awarded to US citizens. Hence, attracting sufficient high-ability US students to science and engineering careers, especially in an environment of flat funding, has become a growing concern. Inspiring such students at the beginning of their careers is a precondition for building an outstanding science and engineering workforce. Students are further encouraged when they are exposed to opportunities for discovery, usually through federally supported research projects under the guidance of their faculty mentor as principal investigator. Training high-ability students for scientific careers is a long, expensive process, and one that requires a strong student commitment. The federal funding role is critical.

So how successful are we in inspiring our high-ability students? A survey of graduates in science and engineering, which was included in the NSB indicators report, measured the satisfaction of recent degree recipients with their field of study. In the physical sciences, the higher the degree level, the more graduates were dissatisfied. Nearly a quarter of recent PhD graduates said they would not choose the same field of study again if they were given the choice. Dissatisfaction with outcomes by a substantial number of the most highly trained personnel in a field poses a deterrent to potential students. One obvious explanation for unhappiness is that principal investigators, who support students on their research grants, are frustrated. They commonly waste time preparing multiple proposals for research project funding, and even excellent proposals fail to receive funding because federal research budgets are inadequate. This clearly sends future students the message that the prospects for a rewarding career in research are poor and the field of study is not valued.

It is imperative that the federal government reaffirm its commitment to support national science and technology through fundamental research and advanced education. To do so adequately, it must dramatically increase investments in basic research, and assure that the process for allocating federal funds produces the greatest benefits for the American public. A renewed federal commitment is critical both for sustaining the flow of new knowledge and for educating the science and engineering workforce that is the foundation of continued US prosperity and security.

I acknowledge the contributions of Jean Pomeroy and other NSF professional staff to this article.

References

1. US Commission on National Security/21st Century, *Road Map for National Security: Imperative for Change*. Available at http://www.nssg.gov/phaseIIIFR.pdf.
2. M. E. Porter, S. Stern, *The New Challenge to America's Prosperity: Findings from the Innovation Index*, Council on Competitiveness, Washington, DC (1999). Also available at http://www.compete.org/pdf/index.pdf.
3. National Science Board, *Science and Engineering Indicators—2002*, rep. no. NSB 02-01, NSF, Arlington, Virginia (April 2002). Available at http://www.nsf.gov/sbe/srs/ seind02.
4. For examples of National Science Board reports, see http://www.nsf.gov/nsb/documents/reports.htm.
5. G. Brumfiel, *Nature* **416**, 251 (2002). ■