IEEE★USA

POSITION STATEMENT

FEDERAL SUPPORT OF FUNDAMENTAL RESEARCH

Adopted by the IEEE-USA Board of Directors (22 Oct. 2019)

IEEE-USA strongly recommends sustained, balanced funding for fundamental research in science, technology, engineering, and mathematics (STEM). Such research provides the foundation for scientific discovery and progress. It helps assure technological leadership and innovation and avoids unanticipated foreign developments of emerging and disruptive technologies—in both the national security and the civilian sectors. Since World War II, the United States has been the world's scientific and engineering leader; and consequently, its economic leader, as well. Federal support for fundamental research in STEM fields has seen a steady decline in the United States over the last 50 years, undermining the foundation for U.S. innovation. Federal investment in long-term, high-risk, high-payoff fundamental (*i.e.*, basic and applied) research is particularly important today, to maintain global science and technology competitiveness.

IEEE-USA recommends that the government work with industry and universities to:

- Maintain a healthy, sustained and balanced fundamental research investment in science, technology, engineering and mathematics, including modern laboratories and equipment.
- Restore fundamental research funding of both civilian and national defense agencies in these areas to a globally competitive level.
- Prioritize scientific and technological fundamental research that is important to ensure scientific leadership, technology competitiveness, economic growth and national security.
- Ensure the committed participation of universities, research institutes and federal laboratories, where much of the innovative and leading-edge fundamental research is conducted.
- Enhance interagency coordination of science and technology related activities, with shared information and planning to encourage the free flow of ideas, while still encouraging independent thinking to stimulate multiple approaches at the early research phase.

- Reduce administrative overhead burden in federally funded research through initiatives—including, but not limited to, streamlining regulations.

- Increase support for science, technology, engineering and mathematics education, including K-12 teacher training, to meet U.S. competitiveness needs in the global economy.

This statement was developed by the IEEE-USA Research and Development Policy Committee and represents the considered judgment of a group of U.S. IEEE members with expertise in the subject field. IEEE-USA advances the public good, and promotes the careers and public policy interests of the nearly 180,000 engineering, computing and allied professionals who are U.S. members of the IEEE. The positions taken by IEEE-USA do not necessarily reflect the views of IEEE, or its other organizational units.

BACKGROUND

Nobel Prize-winner Robert Solow's pioneering study showed that more than half, and perhaps as much as 85 percent of productivity growth in the United States in the first half of the 20th century could be attributed to technical advances.[1] Other studies indicate that 50 percent, or more, of the sevenfold real growth the country has enjoyed since the end of World War II is attributable to technological innovation resulting from investments in research and development.[2]

Fundamental research underpins technological progress. "'Fundamental research' means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons."[3] In turn, the Office of Management and Budget defines these results, as follows: [4]

> *Basic research is defined as systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.*
>
> *Applied research is defined as systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.*

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[1]R. M. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics* **39**, 312–320, 1957.
[2]President's Council of Advisors on Science and Technology, "*Transformation and Opportunity: The Future of the U.S. Research Enterprise*", 2012.
[3]Ronald Reagan, "National Policy on the Transfer of Scientific, Technical and Engineering Information," *National Security Decision Directive 189*, 1985.
[4]Office of Management and Budget, Circular A-11, Part II, Sec. 84.

Maintaining a Healthy, Stable, and Balanced Fundamental Research Investment:

As President Reagan observed, "Although basic research does not begin with a particular practical goal, when you look at the results over the years, it ends up being one of the most practical things government does. Major industries, including television, communications and computer industries, couldn't be where they are today without developments that began with this basic research."[5] Lasers, the Global Positioning System, touch-screen displays, and LED lighting (to name just a few) are other advances based on fundamental research.

Many others share this recognition of the importance of science and engineering research. Senator John Rockefeller emphasized, "There can be absolutely no question that investing in science and technology, in innovation, and in educating our young people is critical to maintaining our nation's global leadership… The money that we put into basic research, into understanding the world around us, has a real-world impact."[6]

Rep. Lamar Smith also succinctly stated the rationale for federal government support of basic research:

> The federal government provides the largest share of funding for basic research. This is a role for which government is uniquely suited. That's because our federal research agencies do not have to make investment decisions based on quarterly profit and loss statements. In other words, government funds the basic research that is the seed corn for our economy.[7]

Economic growth as described by Solow[1] and others[2] requires stable support for research as a fraction of the Gross Domestic Product (GDP). Research funding that does not at least keep pace with the GDP inevitably has a decreasing impact on future GDP growth.

Unfortunately, federal support of science and engineering research declined significantly from 1970 to 1997 and has gyrated wildly since then.[8] See Fig. 1.

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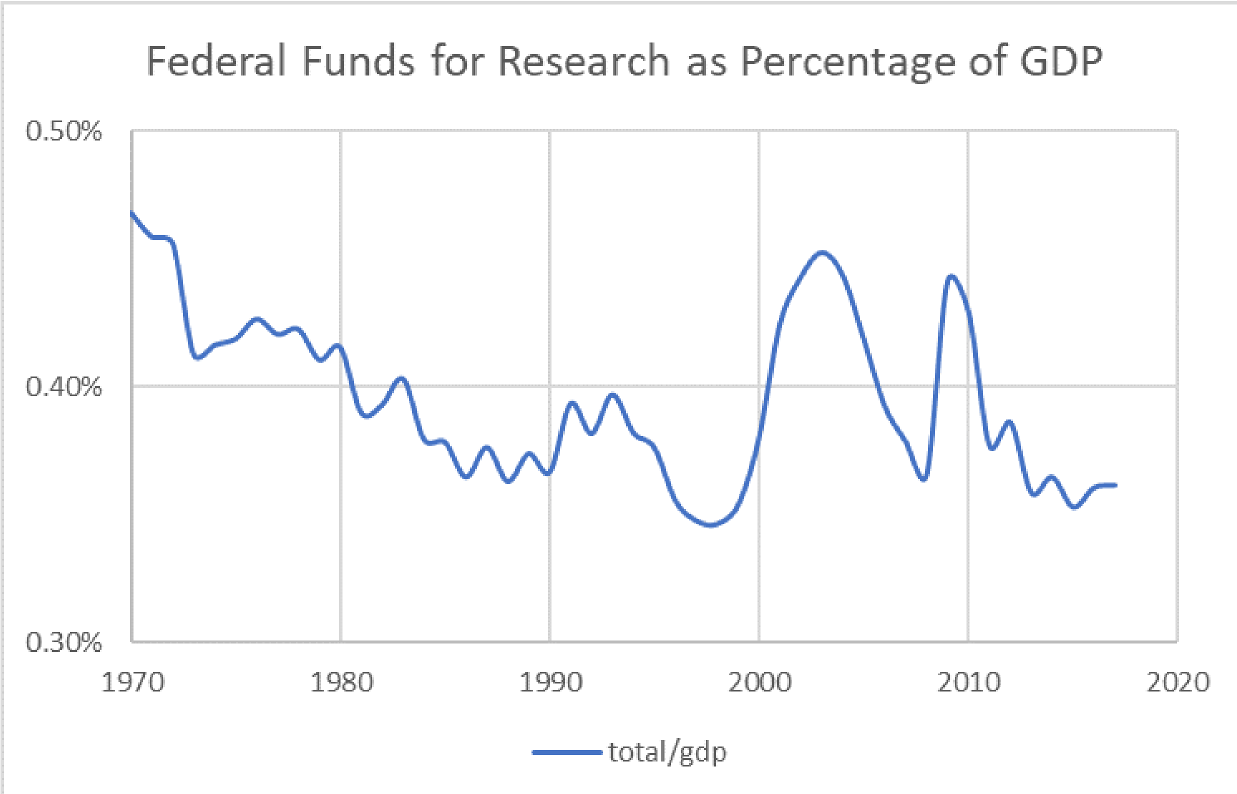
[5]Ronald Reagan, "*Radio Address to the Nation on the Federal Role in Scientific Research*", 2 April 1988.
[6]John Rockefeller IV, in "*Capitalizing on Investments in Research and Development*", U.S Senate hearing, 17 July 2014.
[7]Lamar Smith, "*Smart Spending On R&D Will Keep America Ahead*", *Forbes*, 6 May 2014.
[8] *AAAS Historical R&D Data*. Available at: www.aaas.org/programs/r-d-budget-and-policy/historical-rd-data.

Figure 1



The increase in 2004 was the result of a temporary doubling of the NIH budget. The 2009 spike was the result of a one-year Stimulus Bill.

The full impact of decreased research funding is felt, not immediately, but after a lag time of a few decades. “Since World War II, the United States has led the world in R&D spending. As a direct result, the United States has continued to be first in the world in science and innovation. And our industries and our workers have continued to be the leaders in aerospace, the internet, computer science, healthcare, engineering, and a host of other important areas.

Our place at the head of the global table, however, is not ordained. We must earn it. We must continue to invest wisely. For the first time since the 1940s, we are no longer winning in crucial areas of science and technology. Our share of worldwide, high-tech jobs is decreasing. China’s high-tech exports nearly triple those of the United States.”[7] The Organization for Economic Cooperation and Development’s (OECD) Science, Technology and Industry Scoreboard lists the United States as tenth in Research and Development, as a fraction of GDP.[9]

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[9]Organization for Economic Cooperation and Development, *Innovation for Growth*, http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2013_sti_scoreboard-2013-en, 2013.

A successful example of policy outcomes is found in the U.S. response to Sputnik.[10] Between 1957 and 1961, the federal investment in research and development more than doubled, and total government outlays for basic research at the National Science Foundation and other agencies tripled. Much of this investment went into laboratories at U.S. universities, which were viewed as partners with the federal government in carrying out research vital to the nation's economic well-being and national security. The output of discovery from this investment was extraordinary, and it helped to create an unrivaled basic research enterprise. A 2006 report, commissioned by the White House Office of Science and Technology Policy (OSTP), noted that "For the years that the NDEA provisions were in force … many areas covered by the legislation experienced broad positive trends."[11] As one indicator of this success, the number of U.S. Nobel prize winners in science quadrupled in the second half of the 20th century.

More recently, a National Research Council study on research universities concluded that, "The nation will increase the performance of its research enterprise--by providing steady, predictable streams of funding for research over time. The last decade has seen damaging fluctuations in research appropriations."[12] The impact is, of course, particularly severe for young researchers. Under such circumstances, students' question whether the United States remains committed to technological advancement, and whether a career in science, technology, engineering and mathematics is a wise choice. A related National Academies study on America's research enterprise noted:

> Stable and predictable federal funding encourages talented students to pursue scientific careers, keeps established researchers engaged over a career, and attracts and retains foreign talent. It also supports a diversity of institutions that both fund and conduct research, as well as essential scientific infrastructure — the tools necessary for conducting research. Stable resources are increasingly important to future competitiveness, given the rising investments in research by other countries.[13]

Stable resources include "essential scientific infrastructure — the tools necessary for conducting research."[12] Universities, in particular, often find it difficult to keep their research instrumentation up to date.

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[10] Association of American Universities, *National Defense Education and Innovation Initiative*, https://www.aau.edu/sites/default/files/AAU-Files/Key-Issues/National-Defense-Education-And-Innovation-Initiative.pdf

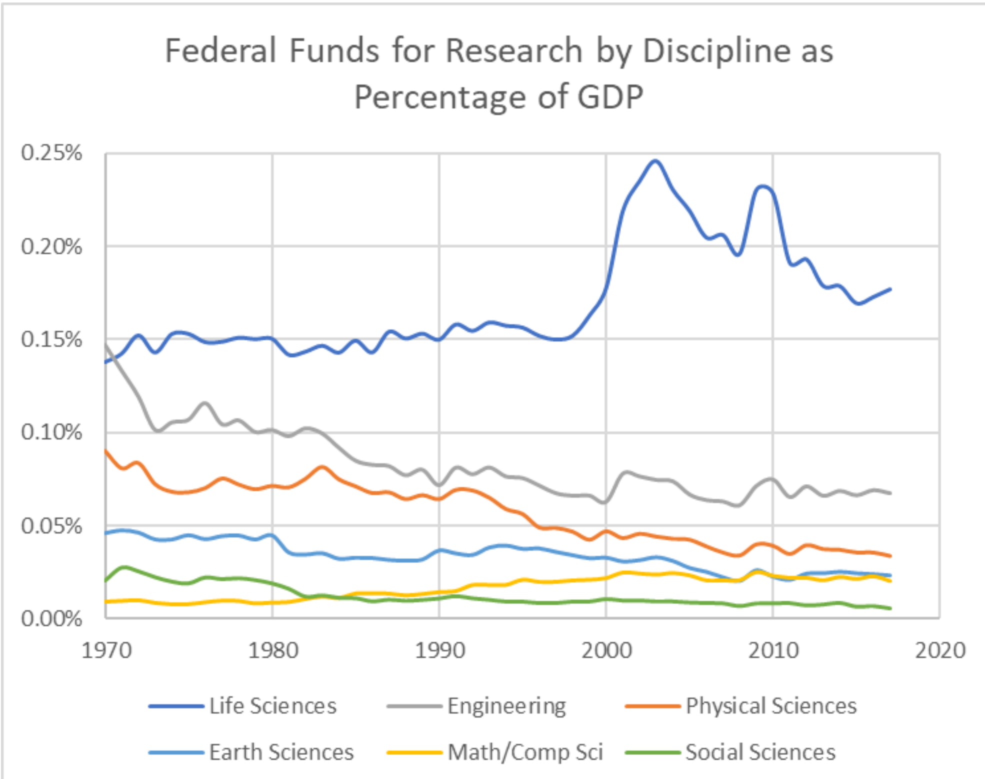
[11] Pamela Ebert Flattau et al., *The National Defense Education Act of 1958: Selected Outcomes*, IDA Document D-3306, March 2006. https://www.ida.org/-/media/feature/publications/t/th/the-national-defense-education-act-of-1958-selected-outcomes/d-3306.ashx

[12] National Research Council, *Research Universities and the Future of America: Ten Breakthrough Actions Vital to Our Nation's Prosperity and Security*, National Academies Press, 2012.

[13] National Research Council, *Furthering America's Research Enterprise*, National Academies Press, 2014.

Federal support of research has also become unbalanced.[14] As Fig. 2 (below) makes clear,[10] federal support for engineering and physical sciences research has declined even more sharply than support for research as a whole.

Figure 2



A healthy economy requires innovative research in a range of disciplines. "Truly transformative scientific discoveries often depend on research in a variety of fields. Maintaining broad expertise among those who conduct research also sustains the innovation system, because technological problems often arise in the development of an innovation that require research for their solutions. Research and innovation are symbiotic in this way."[12] More specifically, as emphasized in *Rising Above the Gathering Storm*, "special attention should go to the physical sciences--engineering, mathematics and information sciences, and to Department of Defense (DOD) basic research funding."[15] (Because the DOD accounts for one-third of all federal investment in engineering, the declining share of federal research funds flowing through DOD strongly impacts the viability of U.S. engineering research. IEEE-USA advocates increased DOD S&T funding.[16]) A nation that leads in medical research, but lags in other key areas, will not fare well in the long-term. Balance is required.

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[14]Stephen Merrill, "Real Numbers: A Perpetual Imbalance?," *Issues in Science and Technology*, Winter, 2013.
[15]Norman Augustine, *et. al.*, *Rising Above the Gathering Storm*, National Academies Press, 2006.
[16]IEEE-USA, "*Department of Defense Science and Technology*," https://ieeeusa.org/wp-content/uploads/2018/08/DefenseST1017.pdf, 2018.

Enhance Interagency Coordination

Better coordination of federal funding agencies could stretch existing research funds further. The National Academies has emphasized that “no agency, office, or committee within the executive branch or Congress systematically monitors the breadth of federal research investments across disciplines and scientific fields in ways that can support the goal of balance and sustainability of the overall scientific research enterprise.”[12]

Enhanced cooperation among agencies might include shared information; coordinated planning and funding; sources for informing the general public of scientific advances, and their impacts;[17] “international benchmarking … to reveal scientific areas pursued elsewhere that may not be adequately supported in the United States;”[18] research and innovation indicators (perhaps building upon IRIS[19] and predecessor initiatives[20, 21]); experiments involving novel research funding strategies;[13] and standardization of proposal submission and reporting requirements. “Much stronger research collaboration between university researchers and federal laboratories, not only those that harbor large experimental facilities but also the other general-purpose laboratories, as well,” would also be of value.[22]

With respect to international benchmarking, there is no substitute for U.S. scientists and engineers (S&Es) attending international research conferences, including those the government employs. More generally, isolating federal S&Es from their peers, foreign or domestic, reduces government access to cutting-edge innovations--and limits the professional growth and effectiveness of its employees.[23]

Although recommending a specific process for coordination among federal S&T funding agencies is not within the scope of this policy paper, IEEE-USA thinks that the suggestion by former presidential science adviser Neal Lane has merit:

> The National Science and Technology Council (NSTC), and its coordinating committees, have done good work, for example, in helping to organize the National Nanotechnology Initiative in the Clinton administration, but the NSTC needs more clout. The White House and Congress should consider authorizing the NSTC; and providing a line of funding in the White House Office of Science and Technology Policy budget for current NSTC staffing and activities — such as reports, workshops and seed funding for interagency cooperative R&D efforts.[17]

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[17]Norman Augustine and Neal Lane, “What if America Had a Plan for Scientific Research?,” *Inside Sources*, http://www.insidesources.com/what-if-america-had-a-plan-for-scientific-research/, 2014.
[18]National Research Council, *Experiments in International Benchmarking of U.S. Research Fields*, National Academies Press, 2000.
[19] IRIS, https://iris.isr.umich.edu/
[20]STAR METRICS, https://www.starmetrics.nih.gov/.
[21]J. Lane and S. Bertuzzi, “Measuring the Results of Science Investments,” *Science* **331**, 678 (2011).
[22]Neal Lane, “Science Policy Tools: Need for an Update”, *Issues in Science and Technology*, Fall, 2011.
[23]IEEE-USA, “Participation in Professional Conferences by Government Scientists and Engineers,” https://ieeeusa.org/wp-content/uploads/2018/08/ProfConferences0618.pdf, 2018.

Increased coordination does not, of course, mean that research-funding agencies should be combined. A diversity of funding agencies helps to assure that a diversity of approaches is employed to address difficult science and engineering problems.

Streamline Regulations

Federal support of fundamental research can have increased impact, if the administrative burden associated with managing this research is reduced. A 2005 Federal Demonstration Partnership (FDP) survey of investigators found that principal investigators (PIs), typically the most experienced scientific and engineering faculty, spent an average of 42 percent of their federally funded research effort on associated administrative tasks, rather than actually performing research. Thirteen years later, and despite federal reform efforts, a 2018 FDP survey found that the average had increased to 44 percent.[24] The National Academies has already identified reducing this excessive burden as a Top 10 priority;[11] and both the Association of American Universities, and the National Science Board, have recommended actions that the federal government can take.[25,26]

STEM Education

Many studies have addressed the importance of a well-qualified, technical professional workforce.[12,13,15, 27] Here, we note the essential role of fundamental research in science, technology, engineering and mathematics education. Most graduate students in these disciplines, many undergraduates, and even some high school students are involved in federally funded fundamental research.

An example of a successful STEM education initiative, some of whose elements could be reenacted today, is the National Defense Education Act (NDEA) of 1958, which provided a highly successful national STEM education and research strategy in response to the Sputnik satellite launch in 1957.[10] The NDEA created new programs to support developing modern curricula in science and math, and to upgrade science teaching quality, by funding training institutes for science teachers.[28] The NDEA also created new graduate fellowships to encourage developing and expanding Ph.D. programs in all disciplines; and increased access to college, via low-interest student loans to undergraduate and graduate students with financial need.

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[24]Sandra Schneider, *2018 Faculty Workload Survey*, Federal Demonstration Partnership, http://thefdp.org/default/assets/File/Presentations/FDP%20FWS3%20Results%20Plenary%20Jan19%20fnl.pdf , 2019.

[25] Tobin Smith, et. al., "Reforming Regulation of Research Universities," *Issues in Science and Technology*, Summer, 2011.

[26] National Science Board, *Reducing Investigators' Administrative Workload for Federally Funded Research*, National Science Foundation, 2014.

[27] National Science and Technology Council, *Charting a Course for Success: America's Strategy for Stem Education,* https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf, 2018.