

**Written Testimony of Dr. Sudip Parikh**  
American Association for the Advancement of Science  
Before the House Budget Committee  
U.S. House of Representatives  
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Chairman Yarmuth, Ranking Member Womack and Members of the Committee, thank you very much for the opportunity to testify before the Committee. I am Sudip Parikh, chief executive officer at the American Association for the Advancement of Science. AAAS is the largest general scientific society in the United States and the world, and the publisher of the *Science* family of journals. Our mission is to advance science, engineering, and innovation throughout the world for the benefit of all people or – put more simply – to advance science and serve society.

The topic of today’s hearing, “Fueling American Innovation and Recovery: The Federal Role in Research and Development,” is incredibly timely for at least three reasons.

**First**, science and engineering are more important now than ever in our national preparation and response to current crises, including COVID-19, and ongoing challenges such as climate change and economic competitiveness.

**Second**, science has a substantive role to play in advancing shared opportunity and fair treatment for all Americans by addressing challenges in the scientific enterprise and providing an evidence base for national policy making.

**Third**, it is time to increase our investments and update our federal policy and investment framework to continue harnessing scientific research and seize the opportunities in front of us to build the U.S. economy and increase the safety and well-being of all Americans.

Today, I will briefly discuss each of these and provide recommendations to the Committee.

**In summary, these recommendations are:**

- 1) The United States should update the Vannevar Bush framework for advancing science and serving society, including prescriptions for how the federal government should coordinate science in response to crises.
- 2) The United States should increase federal investment in R&D as a percentage of GDP to 1.9%, requiring increases of approximately 11% per year.
- 3) Scientific leaders should ensure that the scientific enterprise is supporting opportunities for all by addressing challenges within the scientific enterprise and by providing the evidence base to inform national policymaking.

**Science and engineering are more important now than ever in our national preparation and response to current crises, including COVID-19, and ongoing challenges such as climate change economic competitiveness.**

Preparing and responding to crises and ongoing challenges require leadership and coordination for the efficient allocation of resources. Many investments are being made by government, industry, and philanthropy. But even huge investment is not a guarantee of success. In response to crises, the federal government has a vital leadership and coordination role that can be the difference between success and failure. Successfully preparing for and responding to COVID-19, climate change, and threats to competitiveness will require the federal government to play the role of quarterback.

Science and engineering will be critical to ending the COVID-19 crisis. Evidence-based public health measures, like wearing masks, physical distancing, and contact tracing are needed to slow the progression of the disease until our investments in life sciences and advanced manufacturing deliver vaccines and treatments at a national scale. The basic research and characterization of the novel coronavirus that causes the COVID-19 disease has been extraordinary. In the span of six months, scientists have gone from the first isolation of the virus to a complete molecular characterization of the virus. We have all the basic information required to develop a first round of treatments and vaccines. We haven't gotten the public response right, but the scientific characterization and drive toward treatments and vaccine in very short order is unprecedented. None of this would have been possible without the federal role in research and development.

But COVID-19 is not the only disease affecting Americans during this time. We must ensure that the incredible progress made to lower the death rates for cancer and heart disease continue. For the first time in history, we may be able to cure diseases that have plagued humanity for millennia. Clinical trials are ongoing for what could be cures for sickle cell anemia and beta thalassemia. Patients with night blindness have been cured already. Many more treatments and cures are on the horizon, and none of this is possible without the federal role in research and development and its interplay with the rest of the scientific ecosystem.

To continue to improve our understanding of the climate challenge, we must continue to invest in Earth science missions, as the White House has highlighted through its National Plan for Civil Earth Observations.<sup>1</sup> Reducing carbon emissions and addressing climate change will require science and policy changes. A recent analysis by the International Energy Agency also highlights the importance of technology investments for climate mitigation and response: many of the technologies needed to hit net-zero emissions are still in the early stages, requiring further innovation to achieve cost reductions and performance improvements.<sup>2</sup> The federal government has a clear role to play.

R&D investments are also critical to securing our nation's future in manufacturing. As this Committee well knows, manufacturing employment has declined precipitously for decades. This is not only a challenge to the American middle class, but to our national security since we rely on foreign sources for critical technologies like semiconductors. We also know that R&D investments are critical sources for manufacturing innovation: manufacturers get some of their most important and profitable inventions from sources outside the firm, including universities and startups.<sup>3</sup> Accelerating investments in robotics,

advanced materials, intelligent systems, and related fields can help to restore manufacturing competitiveness.

These are just a few examples of the many areas in which federal leadership, coordination, and investment in science and engineering will be critical to our national preparation and response to current and future crises.

**Science has a substantive role to play in advancing shared opportunity and fair treatment for all Americans by addressing challenges in the scientific enterprise and providing an evidence base for national policy making.**

Scientists have an essential role to play in addressing the systemic inequities we have seen come to the forefront of the public consciousness over the past several weeks. Science, at its core, is the process of removing bias and following evidence wherever it leads. The work of scientists is critical to better understanding and interpreting data on government spending on incarceration, officer-involved shootings, crime reduction, efficacy of police equipment, community policing, and other relevant topics. Science and evidence must be integrated into the policymaking process to advance shared opportunity and fair treatment for all Americans. It is vital to further our understanding of the mechanisms that drive our world and our economy today. To know where we want to go, we must understand where we are, and science—especially social science—is key to unlocking our path forward.

To be able to address national policymaking issues, science must also look inward to ensure that the scientific enterprise is addressing its own biases.

Many scholars have explored the relationship of diversity and excellence, innovation and productivity. We know that our nation’s research and education has far to go to reflect a diverse and inclusive system, and to improve exposure to invention and innovation for people of all backgrounds. Why is this important to innovation and our economy? Science has shown that the diversity of people and cultures that one brings to scientific research and discovery can improve the inputs and the outcomes. Further, enabling broader participation in innovation would allow the United States to achieve a net increase in innovative activities—and that’s good for everyone.

Take the following observation of serial inventor and innovator Joseph DeSimone: “There is no more fertile ground for innovation than a diversity of experience. And that diversity of experience arises from a difference of cultures, ethnicities, and life backgrounds. A successful scientific endeavor is one that attracts a diversity of experience, and cultivates those differences, acknowledging the creativity they spark.”<sup>4</sup>

The core of our nation’s innovation ecosystem is more than just funding for research. As my AAAS colleague Dr. Shirley Malcom stated in Congressional testimony last year, it is also the investment we make in people: “not just the scientists, engineers and mathematicians in our colleges, universities, industries, national labs and biomedical facilities, but also the STEM teachers, technicians, managers, financiers, patent attorneys, and more, whose collective efforts, grounded in science, fuel the innovation economy. STEM knowledge and skills are not just requirements for scientists and engineers but for people throughout the workforce and across the spectrum of our society—from farmers utilizing

weather data and robotics to cultivate and manage crops, to those who care for us when we are sick using unimaginable diagnostic tools.”

At AAAS, we are a gatekeeper organization. Publishing in our journals, serving in our leadership, and winning our fellowships and awards are waypoints to scientific influence and success. We are working to ensure our processes and gatekeeping functions are diverse and inclusive. We are starting with transparency on representation within each of these functions and awards, and providing plans for increasing representation. We must continue to support opportunities for STEM students and professionals across the spectrum of our society. AAAS is working to do this through initiatives such as SEA Change,<sup>5</sup> the Emerging Researchers National Conference,<sup>6</sup> Entry Point!,<sup>7</sup> the L’Oréal USA For Women in Science Fellowship Program,<sup>8</sup> and more – but there is still much work to be done. This work must and will continue and grow – along with work at other scientific societies, government agencies, and in industry.

### **It is time to update our policy and federal investment framework to continue harnessing scientific research for increased well-being.**

Based on the issues, challenges, and opportunities stated above, it is clear that our framework for scientific investment is ready for a refresh. Our nation is celebrating the 75<sup>th</sup> anniversary of *Science: The Endless Frontier*, written by Vannevar Bush in 1945. *The Endless Frontier* provided a policy framework that envisioned a new national partnership between government, academia and industry to harness basic scientific knowledge for security and well-being. It advocated an approach that has become known as the “linear model,” whereby the federal government invests in basic research at universities and laboratories, which in turn catalyzes industrial innovation. Bush’s policy framework has served as the basis for our investment and success in advancing basic research into industrial innovation and economic success for the past 75 years – ***but it’s time for an update.***

Today’s science and innovation ecosystem is far more complex, and the federal role in that system and in society far more varied, than the simple story Bush envisioned. Indeed, some of the greatest instances of value and impact delivered by the federal R&D system only bear minimal resemblance to that vision.

What, exactly, are the ways in which federal R&D investments contribute value to the nation?

**New discoveries from fundamental science.** Federally funded basic research – which seeks fundamental understanding of natural phenomena – has been a staple of the U.S. research enterprise for much of the past century. While Bush’s analysis is overly simplistic for today’s world, it remains true that basic science is vital. While in recent years, industry investment in basic science has risen in certain sectors like pharmaceuticals, electronic instruments, and aerospace,<sup>9</sup> the federal government nevertheless remains the largest funder of basic science in the United States – and the only funder able to sustain long-term investments with highly uncertain and unpredictable outcomes across the full array of scientific disciplines.

As a result, federally funded basic research is a critical source of unexpected but world-changing discoveries. Several years ago, AAAS and partners worked to establish the Golden Goose Award to recognize some of these unexpected achievements, for example:

- The National Science Foundation funded the discovery of a certain kind of bacteria living in the hot springs in Yellowstone National Park. The particular enzymes discovered in this bacterium led to the development of polymerase chain reaction (PCR), a method for replicating billions of DNA copies from small fragments. PCR is a pivotal invention in the annals of science and a foundational tool for modern genetic testing – including COVID-19 testing today.<sup>10</sup>
- Endotoxins are a toxic substance found on the outer walls of bacteria, and are dangerous to humans. Today the *Limulus* amoebocyte lysate (LAL) test is the global standard for screening for endotoxin contamination, with millions of tests performed each year. The test is based on discoveries from research into the circulatory system of horseshoe crabs.<sup>11</sup> The work was funded by the Atomic Energy Commission, the National Institutes of Health, and the U.S. Public Health Service.
- Years of funding support from the National Science Foundation and the U.S. Navy for research into the fundamental properties and amplification of microwave radiation – which was derided at the time as a waste of resources – led directly to the invention of laser technology, as well as a Nobel Prize.<sup>12</sup>

Broadly, federal research is effective in producing discoveries that lead to high-impact, novel inventions, often in technology areas that have not yet received much industry attention.<sup>13</sup> In considering the value of scientific research, it is worth recalling physicist Michael Faraday’s reply in the 1850s to William Gladstone, then British chancellor of the exchequer. Questioned about the practical value of electricity research, Faraday answered: “One day, sir, you may tax it.”

**New technologies and useful knowledge.** The federal government also funds valuable research for nearer-term uses and to address public challenges. It catalyzes the development of next-generation technology in high-risk or underinvested areas. Applied science programs can have major, immediate, and long-lasting impacts on the day-to-day lives of ordinary Americans, and are integral for achieving public missions in health, national security, environmental stewardship, and other areas – especially when they are able to effectively engage users of the knowledge they produce. For example:

- Public agricultural research funded by the U.S. Department of Agriculture (USDA) has produced enormous value for Americans in enhancing agricultural productivity, nutrition, and safety, with very high rates of return on such investments according to recent economic studies.<sup>14</sup> Agricultural innovation has a decidedly regional character,<sup>15</sup> and the benefits of public agricultural research are also regional: public research spending in a given state has a clear effect on technical change, and in turn productivity, in that state and its immediate neighbors.<sup>16</sup> This local orientation toward applied knowledge helped motivate the 1887 establishment of USDA experiment stations via the Hatch Act, which had been in place for over half a century by the time Bush wrote *The Endless Frontier*.
- Particularly relevant to our time, USDA scientists pursue research to understand what are known as zoonotic diseases, those diseases that originate in animals and can jump to humans. For instance, in 2008, the Animal and Plant Health Inspection Service partnered with Agricultural Research Service scientists and the Centers for Disease Control and Prevention (CDC) to implement a swine flu surveillance pilot project. This in turn provided crucial groundwork for surveillance during the subsequent H1N1 outbreak in 2009. As we continue to grapple with COVID-19, USDA’s years of leadership in zoonotic disease science is a valuable resource now and when the next health threat emerges.<sup>17</sup>

- The National Oceanic and Atmospheric Administration (NOAA) has in recent years leveraged the agency's supercomputing resources with data from thousands of U.S. Geological Survey streamgages to deploy the new National Water Model (NWM), a tool that vastly improves flood forecasting across the continental United States. It provides timely, reliable, high-resolution forecasts every hour for millions of river locations that would otherwise not have them, providing utility for emergency responders, local water infrastructure managers, and other local officials.

Some of the most powerful innovations emerging from federal R&D come not from pure serendipity, but from what has been called “connected science” or “channeled curiosity”: the purposeful coupling of risky research with real-world challenges and outcomes.<sup>18</sup>

For example, NSF's Engineering Research Centers (ERC) program is emblematic of this approach, combining fundamental science, technology prototyping, industry partnerships, and sustained long-term support. This approach has yielded hundreds of discoveries, inventions, patents, and patent licenses along with dozens of spinoff firms, returning many millions of dollars to the economy.<sup>19</sup> Successes include, for instance, the first FDA-approved artificial retina in the United States, which in addition to the ERC program's support received funding from NIH and the Department of Energy.<sup>20</sup>

The classic model for this approach is embodied in the Defense Advanced Research Projects Agency (DARPA), which has helped drive world-changing innovations in microelectronics, wireless communications, GPS, synthetic biology, stealth, and other areas. The innovative DARPA model, so valuable for defense technology, has begun to proliferate into other areas of the federal enterprise, with intriguing results.

One advantage of this model is its potential for dual impact on discovery *and* invention, as seen with the achievements of the Advanced Research Projects Agency-Energy (ARPA-E). ARPA-E has been highly effective in advancing fields of science (through new journal articles) and *simultaneously* advancing breakthrough technologies (through new patented inventions),<sup>21</sup> while funding projects that are too risky even for venture capital.<sup>22</sup>

**Skills, networks, and collaborations.** While the popular image of the lone, heroic scientist laboring away in her lab may persist, the reality is modern science and innovation increasingly relies on teamwork. Thus, a major way federal research delivers value is through training talented researchers and engineers supported by the spectrum of federal STEM education programs, and through the creation of knowledge networks.

For instance, DARPA helped to seed the modern field of materials science and engineering by establishing Interdisciplinary Labs in 1960 at Cornell, Northwestern, and the University of Pennsylvania, with several more the following year. The goal of these labs was to pull together the varying disciplinary strands relevant to materials science – including physics, metallurgy, and chemistry – which until then had generally been fragmented in separate university departments, and to produce a generation of skilled materials scientists and engineers able to think in these terms. The lab program was instrumental in creating a new interdisciplinary “materials science” community, and a quarter century later American universities boasted roughly 100 materials science departments.<sup>23</sup>

The idea of knowledge networks and collaborations is also relevant to cluster development and innovative performance. A recent study published by the National Bureau of Economic Research demonstrates that large-scale R&D investments during World War II, from Roosevelt's Office of Scientific Research and Development (OSRD), had long-term effects on American invention and industry. Those regions heaviest in OSRD research contracts during the war saw an explosion in patenting in the years after the war, sustained growth in high-tech industry, and far higher employment in associated manufacturing sectors three decades later.<sup>24</sup> Federal investments catalyzed a blossoming of "entire local research ecosystems" comprising universities and federally funded research centers.

Along similar modern lines, universities – which rely on federal dollars for most research – are increasingly important influences on the inventive activities of nearby firms<sup>25</sup> and on the creation of new startups. Having a ready workforce of skilled science graduates is also important for firm innovation.<sup>26</sup> In the case of the NSF ERCs mentioned above, employers have frequently found ERC graduates to be particularly effective research employees.<sup>27</sup>

**Incentive for investment by others.** Public research funding and partnerships (as well as R&D tax incentives) can serve as a catalyst for follow-on research investment, in some cases substantial. For instance, studies have found that each \$1 increase of NIH basic research has generated an additional \$8 increase in pharmaceutical R&D,<sup>28</sup> while every \$10 million increase for NIH research on a particular disease generates an additional 2.7 additional industry patents in that disease area.<sup>29</sup>

In the energy space, receiving a Phase I award from the Department of Energy's Small Business Innovation Research (SBIR) program raises the odds of follow-on VC investment by up to 19%, and is associated with increased patenting and revenues.<sup>30</sup> And public-private programs like the Manufacturing USA institutes and the ERCs have been effective in eliciting industrial and other partners.

### **Why is government irreplaceable for all of this?**

As mentioned above, industry basic science has increased in certain high-tech sectors. But industry *development* spending has increased even more rapidly. In the *Endless Frontier* era, the federal government was the source of almost two-thirds of all national research and development funding, with industry contributing one-third. Today, the roles are reversed, and industry represents roughly two-thirds of national R&D investments. With this shift toward industrial R&D, is the federal government still vital? The answer is unequivocally yes.

The scientific enterprise has evolved far beyond anything Vannevar Bush imagined in 1945. The vast ecosystem delivers scientific advances, medical cures, innovative technology products, raised standards of living, economic growth, and awe-inspiring understanding of the universe. This ecosystem is nourished by broad and varied federal investment in research and development; university and nonprofit, institute-based scientists driving thought leadership; innovative financial instruments to bring private sector risk capital; entrepreneurs driven to move scientific advances from the lab to the consumer; industry investment, particularly in development; and agile regulatory agencies able to keep up with the progress of science and technology and factor it into decision-making. Each piece of this ecosystem is important, but it all begins with the federal role.

The federal role in research and development also drives the culture of science. This is more important than ever as scientific investment grows around the world, and other nations copy our current model.

The culture of science, human research protections, research integrity, ethics, and diversity (for all its remaining flaws) in the U.S. is hard won – and built upon learning from and correcting many previous mistakes. The U.S. government is the only player in the scientific ecosystem with the heft to ensure that the global culture of science draws from the best of the U.S. enterprise.

For example, openness is a vital ingredient in innovation. The norms of open science are well-established at U.S. universities, and knowledge generated in the academy is able to proliferate through publishing, conferences, and scientist interaction. Collaboration between various kinds of entities – businesses, universities, nonprofit research institutes, and government labs – is a powerful means to innovate. In comparison, most industry R&D is done in-house, and published research from corporate scientists has declined over many years.<sup>31</sup>

In addition, industrial R&D tends to have a built-in bias toward incremental advances and familiar markets rather than breakthroughs or new markets. This is understandable: the profit motive seeks returns, but such returns are highly uncertain when it comes to research investments. Markets seem to have great difficulty valuing research investments in a given firm's portfolio.<sup>32</sup> This is particularly true in certain low-innovation sectors, including legacy sectors like energy, which by definition feature substantial obstacles to disruptive innovation.<sup>33</sup> Thus, research expenditures are often the first to be cut when corporate budgets tighten.<sup>34</sup>

And of course, in addition to the necessities of public research itself, there's also the fact that federally funded research provides a critical training ground for tomorrow's scientists, engineers, innovators, and entrepreneurs.

As VC legend Bill Janeway has written, "The venture capital model is radically unsuited to investment in fundamental science or in technological invention in its nascent stages. For the next generation of entrepreneurs and venture capitalist to have their opportunity to dance, they need government agencies as active and creative as those that served my generation."<sup>35</sup>

## **Rising Foreign Investment**

Our global competitors understand the value of these investments. They have seen the success of Bush's framework – and have paid it the highest compliment: they are copying it. The 2020 State of U.S. Science and Engineering report – part of the Science and Engineering Indicators released by the National Science Board – indicates that although the U.S. still spent more on R&D than any other country in 2017, other nations are catching up.<sup>36</sup> Since 2000, the American share of global R&D has declined from 37% to 25%. China has accounted for nearly a third of the total growth in global R&D in that time, and preliminary data suggest it may have overtaken the U.S. in spending in 2019.

The Benchmarks 2019 report published by the Task Force on American Innovation – to which AAAS contributed – lays out several other metrics in education and other areas reflecting the increasing challenges to U.S. scientific leadership.<sup>37</sup>

We all know the China story, but it's not just China. Just last week, the United Kingdom released a roadmap for U.K. research and development.<sup>38</sup> It's a visionary plan for investing in world-class research, fostering talent, enhancing productivity, and pursuing a place-based approach to ensure all U.K. regions can share in the prosperity. The United States should be answering our own innovation challenges with the same vision and ambition.



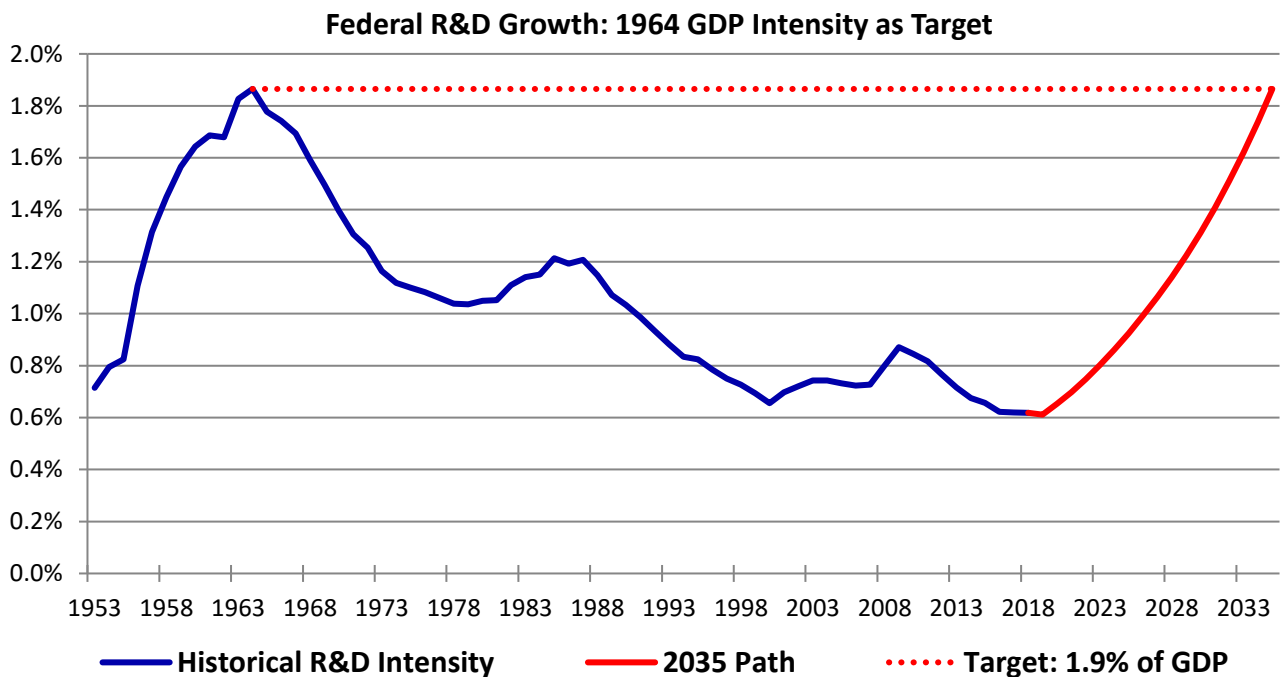
We also face global challenges in the realm of human capital. For instance, based on test scores, U.S. science and mathematics education at the elementary and secondary level is mediocre and stagnant relative to other countries. For decades, the U.S. has relied on foreign-born talent to help meet its S&E job needs. A considerable proportion of U.S. S&E degrees – especially at the doctorate level (34%) – go to international students, many of whom remain in the U.S. after graduating. However, the Indicators data show a troubling shift: foreign student enrollment in U.S. colleges and universities has declined since 2016.<sup>39</sup>

Internationally mobile students still choose the U.S. more than any other country for their higher education degrees – though the effects of the COVID-19 crises have yet to show up in the data. Students today have more choices than ever before as nations actively court globally mobile talent. The United States’ latest actions on legal immigration, combined with the travel restrictions brought about by COVID-19, threaten this key ingredient to our scientific ecosystem.

### U.S. Research & Development Investment has stagnated

U.S. research intensity, R&D as a share of GDP, is well below its peak level and below the investment levels of nine other countries. How much should we invest? There is no one right answer to this, but if we’re to restore American leadership there are a few different ways to think about the scale of the challenge.

One way is to benchmark us against ourselves. Federal funding for research and development peaked in 1964 at 1.9% of GDP. Let’s say you wanted to get the federal government back to this level by 2035. Doing so would require annual increases of about 11% across the enterprise for the next 15 years (see below).



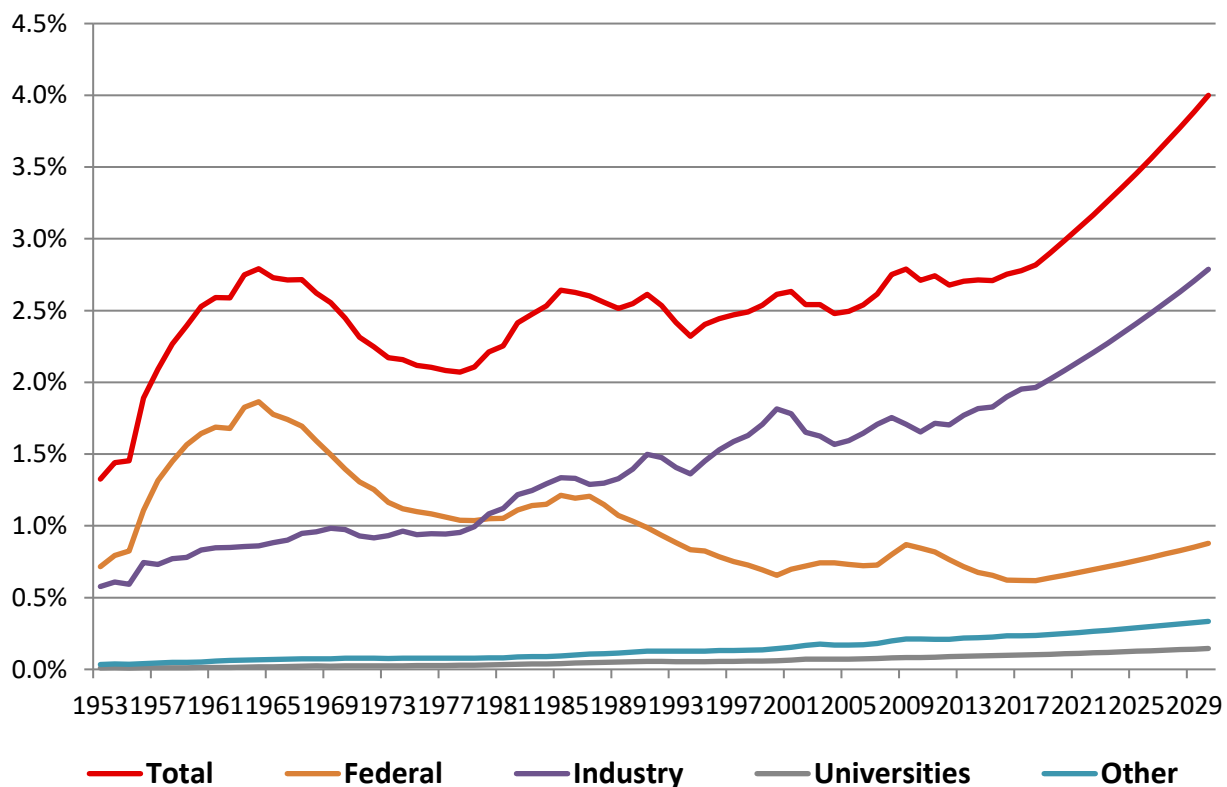
AAAS analysis based on NCSES and CBO data.

Alternately, we could benchmark the United States against the world. Compared to other OECD countries, the U.S. is just hanging on to the top ten in R&D intensity at about 2.8%, behind Israel, Korea, Germany, Taiwan, and others. That includes all R&D from all sources: public, private, academic, and nonprofit.

Let's say you wanted R&D to hit 4% of U.S. GDP by 2030. This would not put us at the top, but it would get us close – into the top three at least, based on current spending by other global leaders. Assuming funding from all sources were to grow proportionately, federal R&D across all agencies would have to grow by about 7% per year (see below). In addition, we may have to adopt additional policies such as a more generous R&D tax credit to attempt to incent additional investment from other sources. And if those other sources are unable to invest more, that would put additional responsibility on government.

As you can see, regaining American leadership and driving innovation will require substantial investments of public resources – and we'll need sufficient budget space to do it.

**R&D as a Share of GDP by Funder: 4% GDP Target by 2030**



AAAS analysis based on NSF and CBO data.

## CONCLUSIONS

We are living in an era in which science and engineering have delivered extraordinary advances that are improving health, well-being, and economic prosperity for Americans and people around the world – and we are on the cusp of even more life-improving developments and discoveries. Despite some

painful mistakes and errors, the American innovation engine has been the envy of the world. But these successes are lagging indicators of legislative, policy, and investment choices made over the last 75 years. Continued success is not guaranteed, but our past willingness to take on risks has shown a high rate of return. Our generation must make wise policy decisions and investment choices now to deliver on continued well-being and economic growth for the next generation.

## RECOMMENDATIONS

- 1) The United States should update the Vannevar Bush framework for advancing science and serving society with an emphasis on full spectrum innovation: including fundamental science, mission-driven technology, and useful knowledge programs that meet local, national, and international needs, with the federal government as a key partner. We shouldn't be afraid to experiment with different ways of funding R&D through different models and networks to meet societal goals, whether it's traditional single-investigator project grants, or people-centered grants, or teams and hubs, or prizes, or other models. The framework should include guidance for how the federal government should coordinate science in response to crises.
- 2) Under this new framework, the United States should increase federal investment in R&D as a percentage of GDP to 1.9%, requiring increases of approximately 11% per year. This would match the peak we achieved more than five decades ago and put us firmly back into the top three countries for research intensity globally.
- 3) Scientific leaders must ensure that the scientific enterprise is supporting opportunities for all by addressing challenges within the scientific enterprise and by providing the evidence base to inform national policymaking. This is critical to ensuring a fairer scientific enterprise and a fairer world.

In closing, thank you for this opportunity to address the value and importance of federal R&D.

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<sup>11</sup> <https://www.goldengooseaward.org/awardees/horseshoe-crab-blood>

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