SPECIAL COMPETITIVE STUDIES PROJECT

Funding for the Future: The Case for Federal R&D Spending

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Federal research and development (R&D) funding is a vast and complex issue involving a multitude of stakeholders from every corner of the innovation ecosystem, including federal, state, and local governments, universities, companies and startups, consortiums, and non-governmental organizations. This paper provides an initial effort to jumpstart a national conversation on how the United States should bolster its investments in American innovation.

Introduction

History has a powerful message: when the United States has the proper resources and political will, it can conquer any technological challenge. Looking back sixty-three years, America set out to put a man on the moon, not only to land on the lunar surface but to unequivocally assert tech leadership against the Soviet Union.[1] To accomplish this goal, the federal government spent $257 billion in today's dollars over thirteen years, conducting fundamental basic research and developing technology that previously did not exist.[2] In addition to showcasing American technological prowess, the original moonshot was about demonstrating the nation's commitment to scientific progress, technological innovation, and, perhaps most importantly, unifying the country around a national effort designed to push the boundaries of human accomplishment.

More recently, the United States confronted a borderless, faceless opponent — COVID-19 — and quickly organized around the need to discover and produce a novel vaccine. Operation Warp Speed spent almost $1.5 billion on vaccine development alone, contributing to the largest yearly increase in federal spending on research and development (R&D) in the last five decades.[3] Out of these federal investments came not only life-saving therapeutics or a "large step for mankind" but also various spinoffs, hundreds of thousands of jobs, and new boundaries for what was scientifically and technologically possible.[4]

Looking ahead, the United States will continue to face a different kind of technological competition amid a new scientific era with boundless opportunities but daunting challenges. Artificial intelligence (AI) alone is rapidly evolving, leading to the boom of generative AI and, eventually, a more general form of artificial intelligence.[5] AI is also converging with other science and tech fields, accelerating the pace of discovery and development. In an increasingly interconnected and digital world, this AI-enabled innovation will be decentralized, readily accessible, and hotly contested among geopolitical rivals. Technology leadership during this moment will fall to the nation that can most readily invent, adopt, and adapt the technologies that will continue to spin out of this innovation "flywheel" at unparalleled and unprecedented speed.[6]

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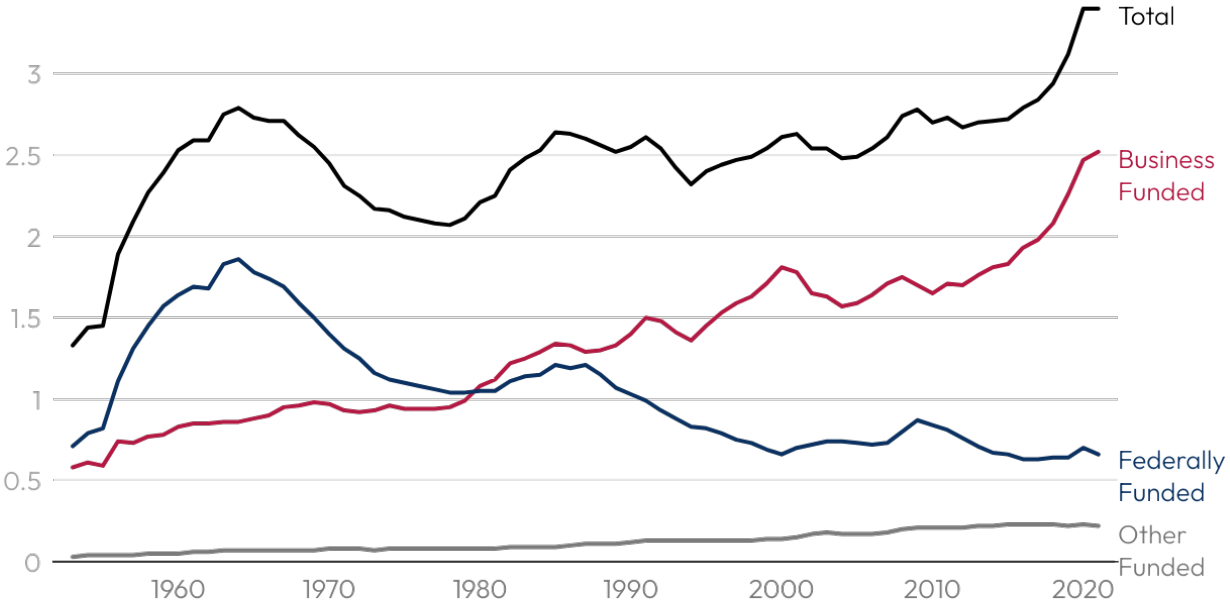
[1] What Was the Space Race?, National Air and Space Museum (2023).
[2] How Much Did the Apollo Program Cost?, The Planetary Society (last accessed 2024); Loura Hall, Going to the Moon Was Hard — But the Benefits Were Huge, For All of Us, National Aeronautics and Space Administration (2019).
[3] Operation Warp Speed Contracts for COVID-19 Vaccines and Ancillary Vaccination Materials, Congressional Research Service (2021); Federal Research and Development: Funding Has Grown Since 2012 and is Concentrated Within a Few Agencies, Government Accountability Office (2022).
[4] Richard Hollingham, Apollo: How Moon Missions Changed the Modern World, BBC (2023); David Adler, Inside Operation Warp Speed: A New Model for Innovation Policy, American Affairs (2021); Gary Hamel & Michele Zanini, America Should Be More Like Operation Warp Speed, The Atlantic (2023).
[5] Innovation Power for the Generative AI Flywheel, Special Competitive Studies Project (2023); Final Report, National Security Commission on Artificial Intelligence at 35-36 (2021).
[6] Innovation Power for the Generative AI Flywheel, Special Competitive Studies Project (2023)

Government investment into R&D is what fuels this ability, and the nation that can harness this new form of state power — innovation power — will be best positioned to lead.[7]

The Current Fiscal Reality

Today, the U.S. government is at a critical juncture where the urgency to act is only matched by tremendous opportunity. However, the United States is underinvesting in R&D and risks faltering at a time when U.S. technological leadership is critical. Government funding for R&D has steadily declined over the past six decades as a percentage of national gross domestic product (GDP) and, between 2010 and 2019 alone, the share of R&D funded by the federal dollars dropped by nearly a third, decreasing the government's ability to make large investments into critical and emerging technologies.[8]

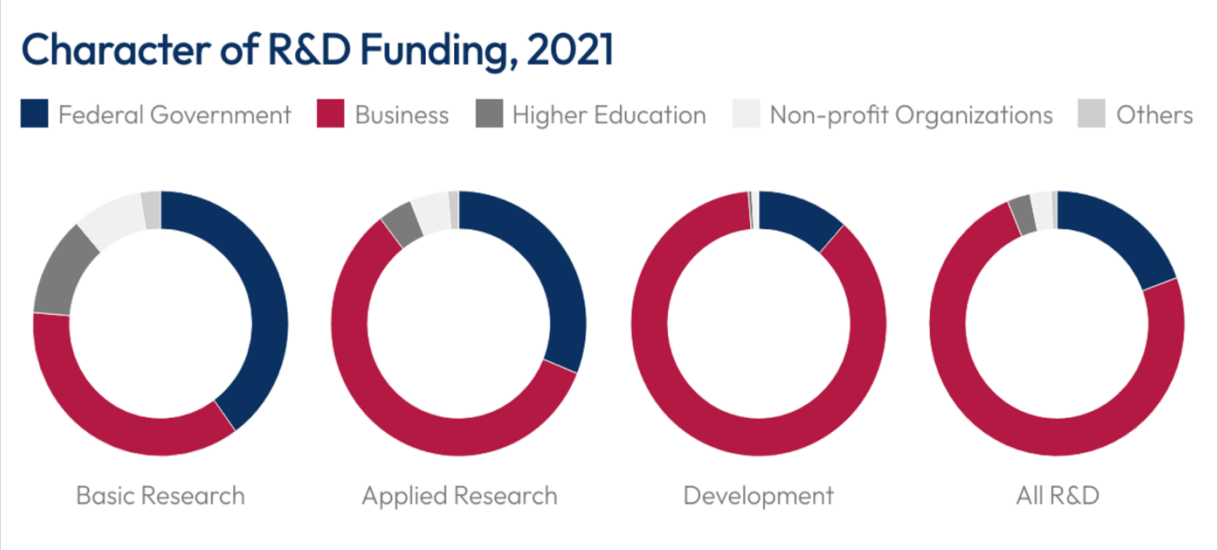
Ratio of U.S. R&D Spending to Gross Domestic Product



Source: Gary Anderson, et al., U.S. R&D Increased by $51 Billion in 2020 to $717 Billion; Estimate for 20221 Indicates Further Increase to $792 Billion, National Center for Science and Engineering and Statistics (2023).

[7] Eric Schmidt, Innovation Power: Why Technology Will Define the Future of Geopolitics, Foreign Affairs (2023); Protecting U.S. Technological Advantage, National Academies of Sciences, Engineering, and Medicine (2022); Rebecca Mandt, et al., Federal R&D Funding: The Bedrock of National Innovation, MIT Science Policy Review (2020).

[8] Gary Anderson, et al., U.S. R&D Increased by $51 Billion in 2020 to $717 Billion; Estimate for 2021 Indicates Further Increase to $792 Billion, National Center for Science and Engineering and Statistics (2023); State of Science in America, Science and Technology Action Committee (2023); Rebecca Mandt, et al., Federal R&D Funding: The Bedrock of National Innovation, MIT Science Policy Review (2020).



Source: National Patterns of R&D Resources, National Center for Science and Engineering Statistics (last accessed January 2024).

America's private sector has traditionally played a leading role in overall R&D spending, resulting in continued breakthroughs, such as the advent of generative AI and its multitude of applications across industry. But the role of government should not be understated. Government spending has historically been the bedrock for scientific breakthroughs and the birth of transformative general-purpose technologies, as was the case with the development of the Internet or mRNA vaccines.[9] Federal dollars also signal areas ripe for additional investment by nudging, creating, or becoming the market for various technological achievements, and thus, create a domino effect by spurring funding from non-federal sources.[10] Therefore, it is important that public and private R&D spending work together to propel the nation forward amid the technology competition.

Every $1 the federal government spends on R&D raises total R&D spending by at least $8.

Source: Erik Britton & Andrew Harris, Welcome to the Machine, Fathom (2023).

While private R&D capital should remain focused on commercialization and shorter deployment timetables, federal R&D dollars should maintain a long view and focus on the interests of what is in the public good and national

[9] Mariana Mazzucato, The Entrepreneurial State: Overlooking the Key Role of the State in Promoting Innovation is One of the Biggest Mistakes of Market Fundamentalism, Soundings (2011); Hussain S. Lalani, et al., US Public Investment in Development of mRNA COVID-19 Vaccines: Retrospective Cohort Study, BMJ (2023); Peter L. Singer, Federally Supported Innovations: 22 Examples of Major Technology Advances that Stem From Federal Research Support, Information Technology and Innovation Foundation (2014).

[10] Mid-Decade Challenges to National Competitiveness, Special Competitive Studies Project at 51 (2022); Rebecca Mandt, et al., Federal R&D Funding: The Bedrock of National Innovation, MIT Science Policy Review (2020).

security.[11] Government R&D funding is necessary to offer patient capital and make sustained investments into areas that will give way to innovation power, and since leadership cannot be left to chance in this era of revolutionary scientific changes, now is the time for the federal government to once again make moon-sized investments in R&D.

A Look at China's R&D Spending

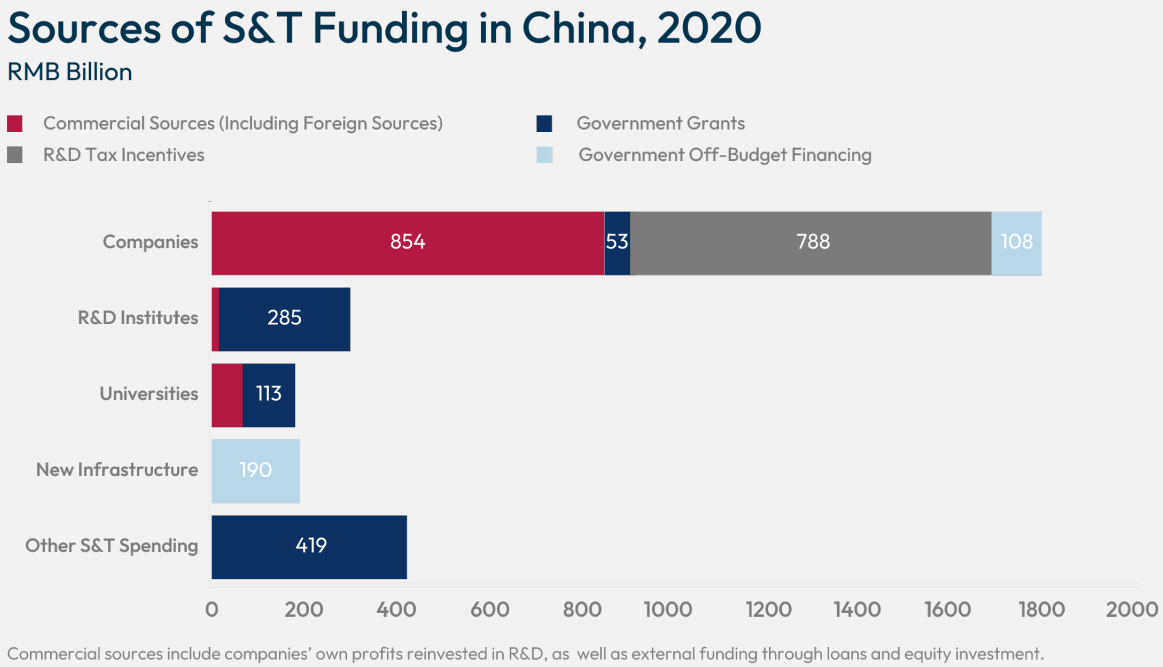
The People's Republic of China (PRC) has made substantial strides in increasing its R&D investments over the past few decades, positioning itself as a formidable player in the technology arena. In early 2023, PRC President Xi Jinping underscored the important role R&D and basic research plays in the country's ability "to cope with international science and technology competition" and to fulfill the Chinese Communist Party's (CCP) aims "to achieve a high level of self-reliance and self-improvement."[12] Combined with its domestic industrial manufacturing prowess, China's R&D investments are helping it build innovation power to spur next-generation technologies for both economic growth and geopolitical influence.[13]

Beijing is backing its words with action. The PRC has increased its total investments in R&D by more than ten percent to reach approximately $421 billion in U.S. dollars in 2022.[14] The CCP explicitly dictates priority tech areas and then follows through with massive government investments to ensure tech development. For example, the government in 2023, launched the largest-ever semiconductor fund totaling US$40 billion to manufacture next-generation chips for the development and widespread application of artificial intelligence — the CCP's number one tech priority – demonstrating its ability to funnel investments toward its national tech goals through various mechanisms like government guidance funds (GCFS).[15] This ability of the Chinese Communist Party to align multiple sources of investment toward national technology goals makes the PRC a formidable competitor in the global technological competition. Even though the United States remains the largest funder of R&D worldwide and leads in private investment in AI, the PRC is quickly spending the resources necessary to catch up and displace the U.S. as the global

[11] Harnessing the New Geometry of Innovation, Special Competitive Studies Project at 26 (2022); Darrell M. West, R&D For the Public Good: Ways to Strengthen Societal Innovation in the United States, Brookings (2022); Matt Hourihan, A Primer on Federal R&D Budget Trends, American Association for the Advancement of Science (2021).

[12] Eduardo Baptista, China's Xi Calls for Tech Self-Reliance Amid U.S. Tension, Reuters (2023).
[13] Dan Wang, China's Hidden Tech Revolution: How Beijing Threatens U.S. Dominance, Foreign Affairs (2023).
[14] Dannie Peng, China's R&D Spending Continues to Grow, but Researchers are Feeling the Pinch, South China Morning Post (2023).
[15] Camille Boullenois, et al., Spread Thin: China's Science and Technology Spending in an Economic Slowdown, Rhodium Group (2023); Testimony of Gregory C. Allen before the U.S.-China Economic and Security Review Commission, China's Pursuit of Defense Technologies: Implications for U.S. and Multilateral Export Control and Investment Screening Regimes (2023); Ngor Luong & Margarita Konaev, In & Out of China: Financial Support for AI Development, Center for Security and Emerging Technology (2023).

technological leader.[16] As the PRC continues to make outsized investments into its science and technology ecosystem, the United States cannot wait to bolster its federal funding for R&D.



Source: Camille Boullenois, et al., Spread Thin: China's Science and Technology Spending in an Economic Slowdown, Rhodium Group (2023.)

A Vision for Funding the Future

- **A Strategic, Coordinated Approach.** The United States needs to develop a vision for federal R&D spending that extends beyond political cycles and encourages interdisciplinary collaboration between the twenty-plus federal departments and agencies that comprise the government science and technology ecosystem, along with the many other research institutions and industry stakeholders.[17] Stable, multi-year funding commitments provide the continuity necessary for successful R&D programs, but such funding streams will only work if the predictability is paired with effective, systematic interagency and stakeholder coordination and engagement.

[16] Alessandra Zimmermann, U.S. R&D and Innovation in a Global Context: The 2023 Data Update, American Association for the Advancement of Science (2023); Camille Boullenois, et al., Spread Thin: China's Science and Technology Spending in an Economic Slowdown, Rhodium Group (2023); Artificial Intelligence Index Report 2023, Stanford University (2023).

[17] State of Science in America, Science and Technology Action Committee (2023).

- **Incentivizing Risk-Taking.** Much of the technology that surrounds us today at one point seemed like a far-fetched idea and only came to fruition when innovators and technologists took calculated risks to achieve breakthroughs. The United States should work to embrace the culture of calculated risk-taking in R&D and make big bets to fuel the next generation of research and development.

- **Building Agility.** New research breakthroughs, technological advancements, and even evolving geopolitical crises can emerge unexpectedly. More flexible R&D funding mechanisms would allow the United States to quickly direct resources toward potential breakthroughs as they arise rather than tethering federal dollars to existing technologies, proven methodologies, or current demonstrations.

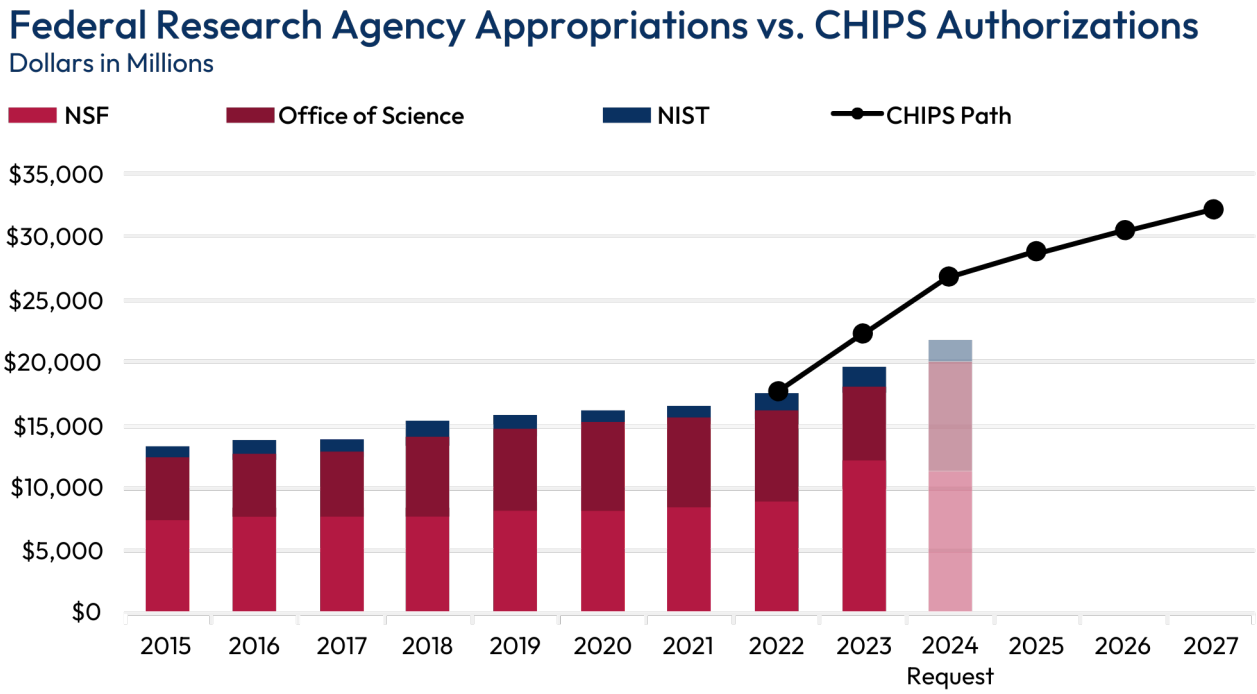
Pathways to Getting Back on Track

To maintain American technological leadership and boost national competitiveness, the United States should increase overall federal R&D spending, bolster funding for AI R&D specifically, and explore ways to improve the federal funding process.

1. Increase Overall Federal R&D Funding to One Percent of GDP by 2030

Increasing federal R&D spending to reach one percent of the nation's gross domestic product (GDP) by 2030 would be an opportunity for the United States to channel the spirit of the Apollo Program and make federal investments into science and technology to nurture innovation and set the nation up for future breakthroughs. The federal government has taken steps to bolster America's R&D enterprise, yet historic legislation, such as the CHIPS and Science Act, remain under appropriated.[18] Today, key R&D agencies face the daunting reality of unmet budget requests and the looming threat of severe budget cuts.[19] To push the nation forward, it is imperative that the United States fully appropriates the authorized funding levels outlined in the CHIPS and Science Act, which would bring the nation one step closer to reaching this ambitious goal of dedicating one percent of GDP to federal R&D by 2030.

[18] Current appropriations are $7 billion short of authorizations in the CHIPS and Science Act. See Matt Hourihan, CHIPS and Science Funding Update: FY2024 Research Appropriations Short by Over $7 Billion, Federation of American Scientists (2023); Fund American Science: Congress Must Act Now to Fund the CHIPS and Science Act, Association of American Universities (2023).
[19] Alessandra Zimmerman, Senate FY 2024 R&D Appropriations: A Review of R&D Intensive Agency Budgets, American Association for the Advancement of Science (2023); Alessandra Zimmerman, Research on R&D Funding: The Impacts of Budget Cuts, American Association for the Advancement of Science (2023); Federal Science Budget Tracker, American Institute of Physics (last accessed 2024).



Based on Agency and Legislative Data and the FY 2024 Budget. Source: Federation of American Scientists

Source: CHIPS and Science Funding Update: FY 2023 Omnibus, FY 2024 Budget Both Short by Billions, Federation of American Scientists (2023)

2. Bolster Non-Defense AI R&D Funding to Reach $32 Billion in Fiscal Year 2026

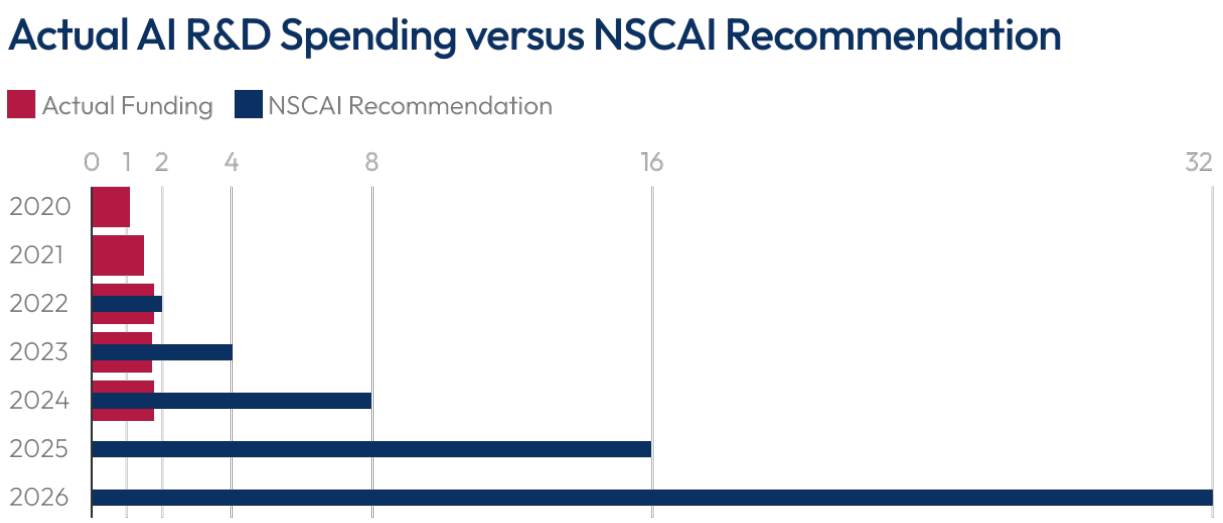
$353.4B

is what the federal government is estimated to spend on R&D in 2030 if federal spending equaled 1% of GDP.

Source: Economic Analyses, Analytical Perspectives, Office of Management and Budget (2023).

Artificial intelligence plays a crucial role in innovation today and tomorrow and cuts across all of the strategic sectors that make up the nation's technological competitiveness. The National Security Commission on AI proposed that federal spending for non-defense AI R&D reach $32 billion by Fiscal Year 2026 — roughly comparable to what the federal government spends on biomedical research.[20] To reach this goal, federal funding for non-defense AI R&D should increase to $8 billion and continue to double annually for the next three fiscal years. Increasing federal funding for AI would foster innovation and scientific breakthroughs by allowing a wide variety of actors to contribute to the field and provide a demand for R&D that is in the nation's interest, such as testing and evaluating frontier models.

[20] Non-defense AI R&D can include research and development of AI itself as well as AI's technological underpinnings and AI-enabled science and tech. See Final Report, National Security Commission on Artificial Intelligence at 188 (2021); Innovation Power for the Generative AI Flywheel, Special Competitive Studies Project (2023).



Source: Artificial Intelligence Investments, Fiscal Year 2019 - Fiscal Year 2024, NITRD (last accessed 2024); Final Report, National Security Commission on Artificial Intelligence at 189 (2021).

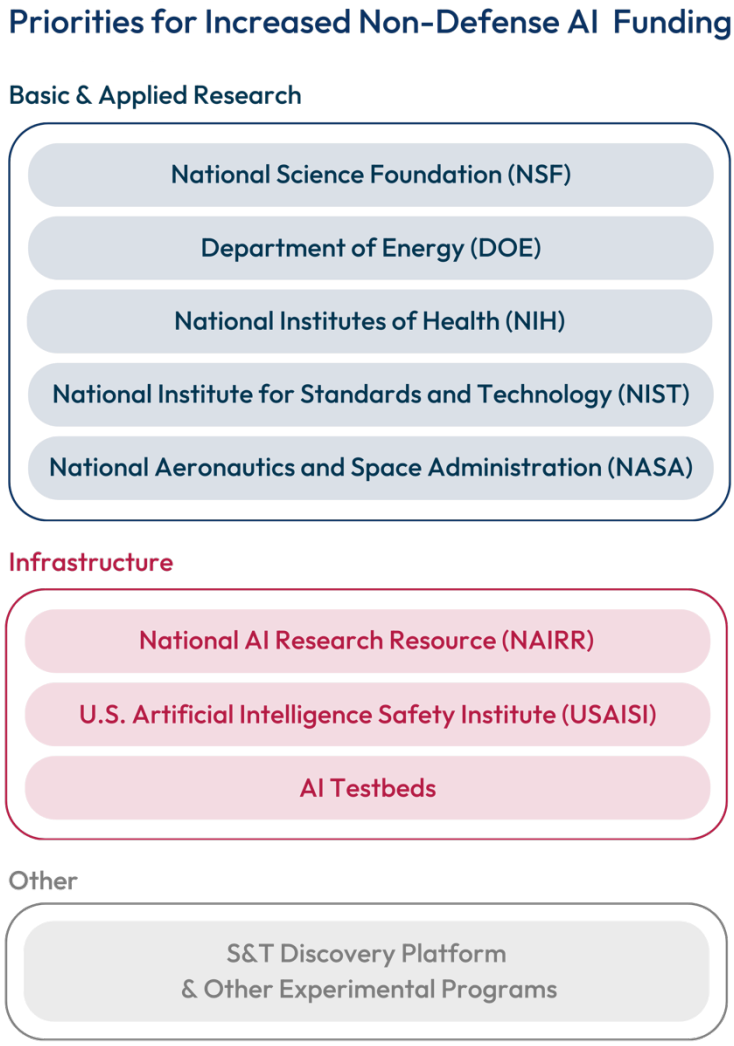
More specifically, an increase in federal spending for non-defense AI research and development should support basic and applied research. These funds should be directed to the government departments and agencies at the forefront of non-defense AI R&D, notably the National Science Foundation (NSF), the Department of Energy (DOE), the National Institutes of Health (NIH), the National Institute of Standards and Technology (NIST), and the National Aeronautics and Space Administration (NASA).[21]

Federal investments in basic and applied AI research should remain agile in anticipation of the rapidly evolving technology landscape. To this end, the federal government should allocate resources to create and enhance critical R&D infrastructure. Initiatives such as the pilot National AI Research Resource (NAIRR), the U.S. Artificial Intelligence Safety Institute (USAISI), and the various AI R&D

Source: National Artificial Intelligence Research and Development Strategic Plan 2023 Update, National Science and Technology Council (2023).

[21] Final Report, National Security Commission on Artificial Intelligence at 188 (2021). See also Supplement to the President's FY 2024 Budget, Networking and Information Technology R&D Program and National Artificial Intelligence Initiative Office (2023); Congressional Research Service, Federal Research & Development Funding FY 2024, (2023); Federal Research and Development: Funding Has Grown Since 2012 and is Concentrated Within a Few Agencies, Government Accountability Office (2022).

testbeds deserve priority funding.[22] More experimental types of programs could include developing an "S&T Discovery Platform" or a proprietary AI model for science within one of DOE's national laboratories.[23] This strategic allocation of resources will not only drive innovation but also ensure that the United States maintains a leading role in the realm of AI.



3.Continue to Explore Ways to Improve the Federal Funding Process

Lastly, we need more than just increased federal funding to maintain national technology leadership. It is time for a revitalized federal funding process that is agile and matches the new, quick-paced era of scientific discovery and technological development. For example, amid the global COVID-19 pandemic, the National Science Foundation's RAPID (Rapid Response Research) and EAGER (EArly-concept Grants for Exploratory Research) programs drastically shortened the time researchers had to wait for federal dollars from almost a year to less than a month.[24] Agencies and departments should also consider alternative funding models, such as issuing awards for milestones rather than waiting for project demonstration or completion, especially when

[22] EO 14110, Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence, The White House (2023); U.S. Artificial Intelligence Safety Institute, National Institute of Standards and Technology (last accessed 2024); AI R&D Testbed Inventory, NITRD (last accessed 2024).

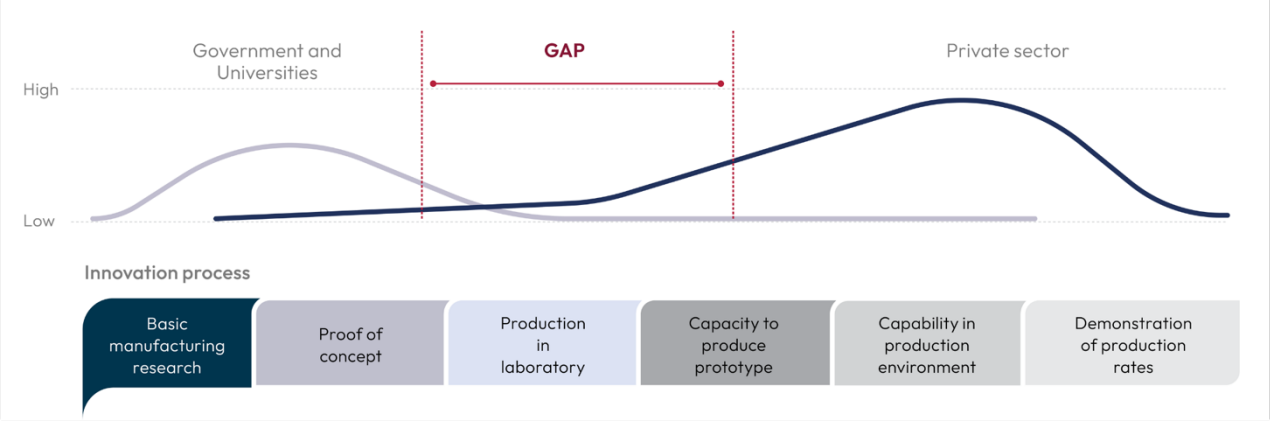
[23] DOE's national laboratories have proposed a program called "Frontiers for AI in Security and Technology" or "FASST'' that would build an AI-driven platform to solve scientific problems. This specific initiative would sit under the DOE's Office of Science and the National Nuclear Security Administration. See Testimony by Divyansh Kaushik before the Senate Energy and Resources Committee, Recent Advances in Artificial Intelligence and The Department of Energy's Role in Ensuring U.S. Competitiveness and Security In Emerging Technologies (2023); Maintaining American Leadership in Artificial Intelligence Through Public Investment and Workforce Development, Joint Economic Committee Democrats (2023) Argonne National Laboratory's AuroraGPT, a generative AI model for scientific discovery, offers another example of a program that establishes a "S&T Discovery Platform." See Training of 1-Trillion Parameter Scientific AI Begins, HPC Wire (2023). See also Innovation Power for the Generative AI Flywheel, Special Competitive Studies Project (2023); EO 14110, Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence, The White House (2023).

[24] Maxwell Tabarrok, How the NSF Moved Faster than the NIH During COVID-19, Institute for Progress (2023).

technological achievement requires incremental progress, like delivering fusion energy plants to the grid.[25]

Other avenues for changing the federal funding process include: 1) establishing new and utilizing existing program-agnostic funds, like an "Overseas Contingency Fund"[26] or the National Institutes of Health's Common Fund,[27] to offer flexible mechanisms by which government can invest in unanticipated game-changing technologies; 2) implementing reforms in the peer-review system to incentivize more risk-taking in R&D ventures, like a "golden ticket" system or a national research lottery;[28] and 3) and encouraging the movement of R&D projects from an idea, over the valley of death, and into a technical reality.[29]

Funding Gap for Commercializing New Technologies



Source: Harnessing the New Geometry of Innovation, Special Competitive Studies Project at 42 (2022).

[25] See L. Rafael Reif, How to Build Upon Vannevar Bush's "Wild Garden" to Cultivate Solutions to Human Needs, Issues in Science and Technology (2021); Fred H. Gage & Eric D. Isaacs, Independent Science for a Daunting Future, Issues in Science and Technology (2022); From the Lab to the Grid: An Action Plan for U.S. Advantage in Fusion Energy, Special Competitive Studies Project (2023).
[26] The Overseas Contingency Operations is a separate fund from the Department of Defense's base funding, allocating funding to support emergencies. A similar-type of fund could be utilized by other agencies and departments to quickly move funding to support the R&D of critical technologies. See FY2022 NDAA: Overseas Contingency Operations, Congressional Research Service (2022); Innovation Power for the Generative AI Flywheel, Special Competitive Studies Project (2023).
[27] NIH's Common Fund supports scientific programs that catalyze discovery across all biomedical and behavioral research, fostering collaboration across NIH Institutes and multidisciplinary, innovative research. Programs funded by the Common Fund are transformative; catalytic, short-term,and goal driven; enabling; cross-cutting, and novel. This type of funding model could be utilized by other R&D agencies to spur similar kinds of R&D within their respective fields. See Who We Are and What We Do, National Institutes of Health (last accessed by 2024).
[28] A "golden ticket" funding mechanism or a national research lottery could allow for bold ideas to bypass unanimous support of the peer review system, which can be risk-averse. A "golden ticket" could grant peer reviewers the chance to override or veto decisions of their colleagues to fund high-risk, high-reward research, or a national research lottery could select proposals out of a separate pool of grant applications to offer one-time funding for more cutting-edge R&D. See Dalmeet Singh Chawla, 'Golden tickets' on the Cards for NSF Grant Reviewers, Nature (2023); M. Anthony Mills, Fix Science, Don't Just Fund It, Innovation Frontier Project (2021); Kelsey Piper, Can a New Approach to Funding Scientific Research Unlock Innovation?, Vox (2021).
[29] Harnessing the New Geometry of Innovation, Special Competitive Studies Project at 42 (2022).

Conclusion

Boosting the federal R&D budget is America's pathway toward accelerated economic growth, stronger national security, and innovative technological leadership at a time when AI and its convergence with other sectors is bringing a new dawn of scientific possibilities.[30] Government investment plays a pivotal role by laying the groundwork for future technologies. It has the potential to create markets for future products and attract additional investments from outside the federal sphere. The United States, now more than ever, should increase federal funding for R&D writ large to reach one percent of GDP by 2030, bolster its investments in artificial intelligence to reach $32 billion by 2026, and consider ways to reinvision the federal funding process. By doing so, the government ensures that America cannot only adopt and adapt to the technologies of today but be able to invent and shape those of the future.

[30] Dimitri Zabelin, Why Government-backed R&D Pays for Itself in Tech, Jobs and More, World Economic Forum (2023); Robert D. Atkinson, Five Free-Market Myths about Increasing Federal Research Funding, Information Technology and Innovation Foundation (2021).