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Government Research

ABSTRACT. Legal scholars have long recognized that the patent system is only one tool among many in law and policy for incentivizing innovation. The innovation-law toolkit includes a host of other institutions, most prominently innovation prizes, research-and-development (R&D) tax credits, and government-funded research grants. Scholars have assessed how each of these, like patents, directs R&D resources toward promising projects, motivates strong performance by researchers, and rewards success. Grants loom particularly large in these analyses, as the federal government remains by far the single largest funder of research in the U.S. economy. In the grant system, the government funds research projects that patents often fail to incentivize, and relies on contractors in academia and industry to perform the R&D.

Conspicuously absent in the innovation-law literature is the role of research conducted by the government itself. The federal government is not only the nation's largest funder of research but also its largest performer. So-called "intramural" R&D conducted by federal agencies, national laboratories, and other government-funded R&D centers comprises a considerable portion—in recent years, close to half—of the government's overall research budget. Given its historical and continuing importance to national innovation efforts, government research should be conceptualized as a distinct paradigm in the innovation-law toolkit.

In this Article, I provide the first comprehensive analysis of government research from an innovation-law perspective. I outline the basic institutional design of government research and, using case studies of the National Institutes of Health Intramural Research Program and Lawrence Livermore National Laboratory, show how it works in practice. I then identify a particular niche in which government research has clear comparative advantages: high-risk, high-reward projects that require massive scale, interdisciplinary collaboration, and long-term funding. I also explore normative justifications for government research beyond efficient knowledge production, including the building of state capacity for developmental policy and a more equitable distribution of the gains from innovation. By integrating government research into this broader institutional framework, this Article reaffirms the state's indispensable role in innovation law and policy and reasserts the values that ought to guide its future development.

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INTRODUCTION

In early January 2020, with the COVID-19 virus spreading rapidly across national borders, a research team in Bethesda, Maryland, began work on a world-changing innovation. Led by Drs. Barney Graham and Kizzmekia Corbett, this interdisciplinary team included many of the world's leading vaccinologists and touted an illustrious record in vaccine development for prior pandemics, including other coronaviruses.[1] With ample funding and the ability to mobilize it immediately in a new direction, the research team received the genomic sequence of the new virus and quickly identified the "spike protein" that would serve as an optimal immunogen.[2]

Leveraging a longstanding collaboration with a large pharmaceutical firm, the team paired the immunogen with a promising new vaccine platform technology, mRNA.[3] The product was soon tested in clinical trials, benefiting from the research group's access to a large clinical-trial population and to an even larger external network.[4] The end result: the Moderna COVID-19 vaccine, a shot with unprecedented efficacy developed and delivered in record time.[5] Over two hundred million doses later, this innovation, along with the similarly structured Pfizer-BioNTech vaccine, dramatically halted the course of the pandemic and saved millions of lives.[6]

The Moderna vaccine embodies the innovation process at its best: world-class researchers with wide-ranging expertise quickly and efficiently working together to solve a problem of enormous public importance. However, the vaccine's name—identifying only one of the key partners in this collaboration—has worked to obscure the true origins of this groundbreaking innovation.[7] The researchers who made the critical contributions in identifying the optimal

1. *See* ANTHONY FAUCI, ON CALL: A DOCTOR'S JOURNEY IN PUBLIC SERVICE 351-52 (2024).
2. *See* Alice Park & Jamie Ducharme, *2021 Heroes of the Year: The Miracle Workers*, TIME (Dec. 13, 2021, 7:41 AM EST), https://time.com/heroes-of-the-year-2021-vaccine-scientists [https://perma.cc/QSK2-232H].
3. *See id.*
4. *Id.*
5. *Id.*
6. Virat Agrawal, Neeraj Sood & Christopher M. Whaley, *The Impact of the Global COVID-19 Vaccination Campaign on All-Cause Mortality* 19 (Nat'l Bureau of Econ. Rsch., Working Paper No. 31812, 2023), https://www.nber.org/system/files/working_papers/w31812/w31812.pdf [https://perma.cc/JJ8Z-4ADU].
7. Christopher J. Morten, *The NIH-Moderna Vaccine: Public Science, Private Profit, and Lessons for the Future*, 51 J.L. MED. & ETHICS 35, 36 (2023) (reviewing the critical role of earlier government-backed research projects in the development of the vaccine and suggesting that "Moderna's reliance on NIH in 2020 has not stopped the company from exaggerating its own scientific role in the years since").

immunogen were neither corporate research-and-development (R&D) scientists nor professors in a university biomedical department. Drs. Graham and Corbett were government employees—civil servants—whose team was based at the Vaccine Research Center (VRC), a government-owned, government-operated research division at the National Institute of Allergy and Infectious Diseases (NIAID), one of the twenty-seven institutes comprising the National Institutes of Health (NIH).[8]

Looking back at the development of the Moderna vaccine, former NIAID Director Dr. Anthony Fauci attributes much of its success to the particular strengths of government-led research at the VRC: an interdisciplinary team, access to substantial resources, and the ability "to turn on a dime" in a moment of crisis.[9] Noting these characteristics, Dr. Francis Collins, the former director of the NIH, describes the VRC as a research group that would be "difficult to fund" with grants as opposed to institutionalized government funding.[10] In the 1990s, Fauci helped establish the VRC, originally tasked with pursuing a vaccine for human immunodeficiency virus (HIV) and envisioned as a research program that could catalyze "the close interaction and collaboration of basic scientists such as immunologists, virologists, structural biologists, vaccine experts, and other scientists, together with clinicians" all under one roof.[11] Since then, the VRC has served as a stronghold for world-leading vaccine research and helped combat severe acute respiratory syndrome, bird flu, Ebola, Zika, and finally COVID-19.[12]

The VRC's achievements are remarkable but not unique. Across myriad technological fields for well over a century, research both funded and performed by the government—so-called "intramural" R&D—has had a transformative impact on technological development and the direction of the U.S. economy. The success stories in government research constitute a highlight reel of some of the most significant scientific advances since the rise of rationalized R&D in the late nineteenth century.[13] Government research programs have been at the center of global technological events whose names are now synonymous with radical scientific advances: the Manhattan Project, Project Mercury, and the Apollo

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8. Park & Ducharme, *supra* note 2; *see also List of Institutes and Centers*, NAT'L INSTS. HEALTH (Jan. 15, 2025), https://www.nih.gov/institutes-nih/list-institutes-centers [https://perma.cc/K4SL-8P84] (listing and describing the institutes and centers of the National Institutes of Health).

9. Zoom Interview with Anthony Fauci, Former Dir., Nat'l Inst. of Allergy & Infectious Diseases (Oct. 11, 2024).

10. Zoom Interview with Francis Collins, Former Dir., Nat'l Insts. of Health (Oct. 31, 2024).

11. FAUCI, *supra* note 1, at 144.

12. *Id.* at 146.

13. For a discussion of the history of the intramural system, see *infra* Section II.A.1.

Program.[14] Government research has also contributed to countless other incremental advances in the gradual march of technological progress.[15]

Innovation-law-and-policy scholarship has, however, overlooked government research. Legal scholars have long recognized that innovation can be incentivized by many different tools in law and policy.[16] The patent system is one such tool and, as the foundational legal framework for promoting innovation in a market economy, it is fittingly the most prominent in innovation-law scholarship. But other alternative or complementary institutions to intellectual property (IP) can accomplish the same underlying task. Lawyers and economists have expanded the innovation-policy toolkit to include a host of other levers, most notably innovation prizes,[17] R&D tax credits,[18] and government-funded research grants.[19] Like the patent system, each of these alternatives channels resources toward promising projects, provides incentives to motivate researchers, and rewards success. A rich literature has developed to assess the relative strengths of these innovation levers, the contexts in which they work best, and the normative concerns that they each implicate. The result of this work is a more nuanced and informed approach to innovation policy.

Growing appreciation for the importance of the grant system is welcome, given the federal government's outsize role in the national R&D effort as the primary sponsor of academic research through grants.[20] Considering federal grant-funding agencies as arms of a single system, the U.S. government is by far the largest funder of research domestically and perhaps internationally.[21] Grants coexist with the patent system and perform a different function, providing backing

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14. *See infra* Section II.A.1.

15. *See infra* Section II.A.1.

16. *See, e.g.*, Brett Frischmann & Mark P. McKenna, *Comparative Analysis of Innovation Failures and Institutions in Context*, 57 HOU. L. REV. 313, 316-17 (2019); Nancy Gallini & Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, *in* 2 INNOVATION POLICY AND THE ECONOMY 51, 51 (Adam B. Jaffe, Josh Lerner & Scott Stern eds., 2002).

17. *See generally* Michael Abramowicz, *Perfecting Patent Prizes*, 56 VAND. L. REV. 115 (2003) (arguing for improving the patent-prize system to incentivize innovation); Michael J. Burstein & Fiona E. Murray, *Innovation Prizes in Practice and Theory*, 29 HARV. J.L. & TECH. 401 (2016) (advocating for achieving technology-policy goals through innovation prizes); Benjamin N. Roin, *Intellectual Property Versus Prizes: Reframing the Debate*, 81 U. CHI. L. REV. 999 (2014) (arguing that intellectual property can be a more effective way to incentivize innovation than prizes).

18. *See generally* Daniel J. Hemel & Lisa Larrimore Ouellette, *Beyond the Patents-Prizes Debate*, 92 TEX. L. REV. 303 (2013) (discussing the role of tax incentives in increasing innovation).

19. *See generally* W. Nicholson Price II, *Grants*, 34 BERKELEY TECH. L.J. 1 (2019) (noting the use of grants to promote innovation).

20. For a discussion of the relative size of the federal grant system, see *infra* Section II.A.2.

21. *See infra* Section II.A.2.

for research projects that patents fail to incentivize. The grant system works as an innovation lever due to specific institutional-design choices that ensure high-quality research projects, despite the lack of patent-based accountability mechanisms and incentives.[22]

The federal government is not only the nation's largest patron of research but also its largest performer. Intramural R&D conducted in federal agencies, national laboratories, and other government-funded R&D centers across the country comprises a considerable portion—in recent years, around forty-five percent—of the government's overall research budget.[23] Like other innovation institutions, government research gives shape and structure to the research process, possesses practical comparative advantages in certain contexts, and invokes normative concerns beyond efficient knowledge production.[24] But it does so in ways distinct from grants, patents, prizes, and all others in the list.

In this Article, I provide the first comprehensive analysis of government research from an innovation-law perspective. By doing so, I aim to make two contributions to the innovation-law literature. First, by explicitly describing how government research differs from the grant system, I introduce government research as a new entry in the core list of institutions analyzed by innovation-law scholars. Second, I provide an assessment of government research as a lever of innovation through both practical and normative lenses. In assessing the former, I appraise this lever's relative strengths in maximizing socially desirable innovation efficiently—in keeping with the baseline framework used across much of the literature comparing innovation institutions. For the latter, I explore normative justifications and benefits to government research beyond this baseline. While some of these alternative value propositions—such as distributional fairness—have been analyzed in the innovation-law literature, others are imported from beyond IP and implicate concerns not typically considered in this field. I thus treat government research as an important target of analysis in itself and as a window to open the field of innovation law to new normative commitments.

While my intervention responds primarily to the scholarship comparing different modes of innovation incentives, I also aim to build on the nascent literature analyzing latent forms of industrial policy in the administrative state as legal

22. *See* Price, *supra* note 19, at 41-63 (describing the benefits of the grant system).

23. Nat'l Ctr. for Sci. & Eng'g Stat., *Survey of Federal Funds for Research and Development 2021-2022*, NAT'L SCI. FOUND. (2023), https://ncses.nsf.gov/surveys/federal-funds-research-development/2021-2022#data [https://perma.cc/95FH-QUK5].

24. For further discussion of these differences, see *infra* Part III.

objects.[25] This emerging field responds, in large part, to the recent revival of sectoral planning on the national stage and the increased politicization of federal research.[26] After decades of the neoliberal taboo on any state intervention that might "pick winners," the "new industrial policy" has shed this reservation and embraced subsidies and direct government provision of goods and services as primary tools for maintaining the United States's position on the global technological frontier.[27] Like the grant system, direct provision of new knowledge through government research would seem to be a prime mechanism in the state's sectoral-planning apparatus.[28] Some policy analysts have even looked to state-led innovation as a core pillar of a new production-oriented direction for American liberalism.[29] It is thus an opportune time to import into the innovation-law toolkit a foundational lever of industrial policy and attempt to understand its basic mechanics.

While interest in and enthusiasm for state-supported innovation is growing among liberals and the left, the second Trump Administration has launched the most significant assault on the federal research system since its birth during the

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25. For work on subsidies, see generally Jeff Gordon, The Problem of Concentrated Subsidies (Apr. 10, 2025) (unpublished manuscript) (on file with author); and Gillian E. Metzger, *Taking Appropriations Seriously*, 121 COLUM. L. REV. 1075 (2021), which argues that doctrine marginalizes appropriations and weakens Congress's spending power. Price, *supra* note 19, which argues for the deconcentration of subsidies, might also be placed in this category. For earlier work on the subject, see generally David E. Engdahl, *The Spending Power*, 44 DUKE L.J. 1 (1994), which discusses the legal contours of congressional spending.

26. For recent legal scholarship responding to the revival of industrial policy, see generally Amy Kapczynski & Joel Michaels, *Administering a Democratic Industrial Policy*, 18 HARV. L. & POL'Y REV. 279 (2024), which outlines how industrial policy can build both administrative and countervailing power to advance its democratic development goals; and James Si Zeng, *Law and Industrial Policy: The East Asian Experience*, 58 VAND. J. TRANSNAT'L L. 197 (2025), which examines the interplay between industrial policy, development, and the economic analysis of law.

27. *See* Laura Tyson & John Zysman, *The New Industrial Policy and Its Critics*, PROJECT SYNDICATE (Nov. 17, 2023), https://www.project-syndicate.org/onpoint/the-case-for-new-industrial-policy-by-laura-tyson-and-john-zysman-2023-11 [https://perma.cc/ER8M-ZTCL] (discussing the revival of industrial policy under the Biden Administration as manifest in the Chips and Science Act, the Inflation Reduction Act, and the Bipartisan Infrastructure Act). For a comprehensive history of the industrial-policy debate in the United States leading up to the neoliberal era, see generally OTIS L. GRAHAM, JR., LOSING TIME: THE INDUSTRIAL POLICY DEBATE (1992).

28. Government support for R&D has long been considered a core part of the development-economics toolkit for countries trying to "catch up" with high-income countries and has been recognized as the backbone of the United States's "hidden industrial policy." *See, e.g.*, Fred Block, *Swimming Against the Current: The Rise of a Hidden Developmental State in the United States*, 36 POL. & SOC'Y 169, 169 (2008).

29. *See, e.g.*, EZRA KLEIN & DEREK THOMPSON, ABUNDANCE 16-18 (2025).

Second World War.[30] The Administration's multipronged attack has cut budgets at critical research institutions,[31] fired thousands of researchers,[32] ended funding for now-politicized research topics,[33] and delayed critical disbursements to universities and other contractors.[34] Government research programs have also been caught in the crossfire of this unprecedented assault on state-backed science,[35] which may still be in its early days at the time of writing. But government-conducted research has received relatively scant attention from policy analysts and journalists, who have focused more on the emerging crisis at universities. This Article offers a corrective and shows that what is at stake in these broad-based attacks on federal R&D is not only the nation's innovative capacity in the near term but also some of the fundamental pillars of an effective and equitable public research system.

This Article proceeds as follows. Part I reviews the existing literature comparing levers of innovation and details the most prominent options in the toolkit: patents, prizes, tax incentives, and grants. I focus in this comparative

30. Dhruv Khullar, *Trump's Agenda Is Undermining American Science*, New Yorker (Mar. 9, 2025), https://www.newyorker.com/magazine/2025/03/17/trumps-agenda-is-undermining-american-science [https://perma.cc/C7NC-GHPF].

31. Aatish Bhatia, Irineo Cabreros, Asmaa Elkeurti & Ethan Singer, *Trump Has Cut Science Funding to Its Lowest Level in Decades*, N.Y. Times (May 22, 2025), https://www.nytimes.com/interactive/2025/05/22/upshot/nsf-grants-trump-cuts.html [https://perma.cc/GY29-XFYW].

32. Jeff Tollefson, Dan Garisto & Heidi Ledford, *Will US Science Survive Trump 2.0?*, Nature (Apr. 29, 2025), https://www.nature.com/articles/d41586-025-01295-6 [https://perma.cc/DY4Y-YV38] ("In its first three months, the Trump Administration has cut many thousands of jobs from science agencies such as the NIH, the Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), the National Oceanic and Atmospheric Administration and the National Institute of Standards and Technology, although exact figures are difficult to tally because the departments have not released the numbers."); Will Stone & Pien Huang, *Health Agencies Lose Staff Members in Key Areas as Trump Firings Set In*, NPR (Feb. 17, 2025, 8:18 PM), https://www.npr.org/sections/shots-health-news/2025/02/17/nx-s1-5300052/federal-employees-layoffs-cdc-nih-fda [https://perma.cc/4RGA-P2P4].

33. Irena Hwang, Jon Huang, Emily Anthes, Blacki Migliozzi & Benjamin Mueller, *The Gutting of America's Medical Research: Here Is Every Canceled or Delayed N.I.H. Grant*, N.Y. Times (June 4, 2025), https://www.nytimes.com/interactive/2025/06/04/health/trump-cuts-nih-grants-research.html [https://perma.cc/66ZC-9572].

34. Dan Garisto, *How Trump Is Following Project 2025's Radical Roadmap to Defund Science*, Nature (Mar. 27, 2025), https://www.nature.com/articles/d41586-025-00780-2 [https://perma.cc/Q6RL-9QRZ].

35. The second Trump Administration has requested substantial cuts to key government research institutions like the U.S. Geological Survey. *See* Erik Stokstad, *Trump Swings Budget Ax at USGS Biology Research*, Science (Apr. 18, 2025), https://www.science.org/content/article/trump-swings-budget-ax-usgs-biology-research [https://perma.cc/9MKJ-R3VQ]. See also Section III.B.1 for a discussion of recent cuts to the National Institutes of Health (NIH) and their effect on the Intramural Research Program (IRP).

review on three key institutional-design choices that cut across each option: who decides what projects to pursue and how much funding to devote to them; when the reward is transferred to the performer; and who subsidizes that reward. Taken together, these choices shape the research process and establish incentives for successful work.

Reviewing recent work analyzing the grant system as an innovation lever, I add to this list a fourth choice in institutional design: who performs the research. In the grant system, the institutional separation of the funder (the government) from the performer (an industrial or academic contractor) embeds in the system mechanisms of accountability and incentives for quality work. Government research, however, has no such separation: R&D projects are both funded and performed by the government. To understand how this lever really works, then, we must go beyond its basic institutional design and examine how it functions in practice.

Part II offers two case studies that delve into these details. I examine two programs that represent prime examples of the two basic models of government research in the federal system: the National Institutes of Health Intramural Research Program and Lawrence Livermore National Laboratory. For each, I provide historical background, an overview of current activities, a detailed look at project-selection and evaluation mechanisms, and a discussion of the various incentives—often nonmonetary—that motivate researchers to perform. What emerges from these case studies is a model of innovation that differs markedly from grants. Government research substitutes the guardrails built into the grant system for a different set of organizational structures, and the result is an innovation model with different comparative advantages.

Part III discusses those advantages and identifies a knowledge-production niche in which government research is more effective than the other levers in the toolkit. Broadly, government research excels at various forms of high-risk, high-reward research that neither patents nor grants can reliably generate. Government research is particularly well suited to projects of a large scale that require unique and massive facilities, projects that benefit from active collaboration between researchers from diverse fields, and projects that require a stable source of funding over the long run. These three advantages—in "big science," "team science," and what we might call "patient science"—define the role of government research in the national innovation system.

Part III also considers justifications for government research beyond its practical advantages in knowledge production. First, I discuss how government research is uniquely generative of state capacity, a critical ingredient for a more effective and robust national industrial policy, in the presence of strong democratic institutions. Much more so than the grant system, government research cultivates expertise in federal bureaucracies and can imbue government work with a sense of public mission—factors critical to building and maintaining a capable developmental state. Second, I examine distributive concerns. Unlike the grant system, which generally transfers rents from state-backed innovation into private hands, government research maintains public ownership of government-funded patents and recoups any resulting revenue. Separately, I suggest that government research programs are more effective at dealing with place-based inequalities that emerge from the clustering effects of innovation-led growth and from the geographic favoritism of the grant system. Government research offers a way to rectify both how and where the direct economic benefits of innovation accrue.

Government research is a powerful tool in the innovation-policy arsenal, but it has limitations, which I discuss in the final Section of Part III. Most significantly, intramural R&D may have greater potential to become politicized and skewed toward ill-advised research topics than other innovation institutions. Though limited by several accountability mechanisms, government research arguably bears greater potential for waste than the grant system, stemming from its larger-scale projects and more stable funding. But this latter point is the flipside of government research's unique strengths: the pursuit of higher-risk, higher-reward research may inevitably entail a higher degree of failure than private firms working in the shadow of the patent system or grant-funded research groups feel they can tolerate.

The critical niche occupied by government research in the national innovation system may become all the more important in the coming decades. The kinds of high-risk projects to which government research is well adapted—large-scale, interdisciplinary, and long-term efforts—likely include some of the century's grand technological challenges. Fusion energy, for example, would reshape the national and global economies and have profound effects on the transition to cleaner energy sources. At the time of writing, this emerging field is squarely in the domain of government research, with national laboratories at the global frontier. Other emerging fields may soon follow suit. Scholars and policymakers would thus do well to add government research to their growing toolkit of innovation levers. Beyond that, those looking for ways to build a more dynamic and equitable economy should see government research as an indispensable institution—one that must be reinforced and defended.

I. THE TOOLKIT OF INNOVATION LAW AND POLICY

Innovation is a notoriously expansive and complex phenomenon. Innovation law and policy follow accordingly. It is widely acknowledged that innovation is perhaps the key driver of long-run economic growth, and that innovation in each society depends in some way on that society's institutions—legal, political, and social.[36] Macro-level institutions, such as political stability and the "strength" of property and contract rights, represent other basic yet crucially important ingredients for an innovative economy.[37] While these fundamental institutions set the stage, states have many tools at their disposal to increase the rate of innovation and alter its direction more actively. Nearly any major area of policy can serve as one of those tools. Education policy, for example, can have the effect of increasing or decreasing a country's supply of scientific workers, which can impact innovation in the aggregate.

The innovation-law toolkit is a smaller carveout of this expansive domain. These "innovation levers" are institutions that bear an immediate relationship to promoting knowledge production; their primary purpose is "to support creative activities that would otherwise not be undertaken."[38] Unlike, say, the size of a country's scientific workforce, which may be an ingredient for innovation writ large, innovation levers generally work to channel resources toward specific projects. They each offer incentives for successful innovative work and structure the research process in different ways. Both legal scholars and economists now recognize that "no one of these schemes has absolute efficiency advantages over the others."[39] Rather, each innovation lever offers distinct comparative strengths suited to certain organizational processes and perhaps even certain technological fields.

Innovation institutions are also generally mutually inclusive. A "pluralist" view of innovation law, in Daniel J. Hemel and Lisa Larrimore Ouellette's framing, accepts that innovation levers can be—and are—fruitfully combined to incentivize innovation and disperse the resulting knowledge goods in different ways.[40] For example, under the Bayh-Dole Act, which established the basic framework for government patent policy, federal grants are in practice combined with the reward of patents for successful projects. As Brett Frischmann noted in one of the first efforts by a legal scholar to perform a comparative analysis of innovation institutions, "[S]ocially efficient production of innovation (of all

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36. A prominent line of thinking in mainstream economics posits that the development, exploitation, and protection of ideas is a primary driver of growth over the long run. The "Endogenous Growth Theory" developed by economists Paul Romer and Robert Lucas is one example of this line of thinking. For another example, see generally DAVID WARSH, KNOWLEDGE AND THE WEALTH OF NATIONS: A STORY OF ECONOMIC DISCOVERY (2007).

37. For a defense of this institutionalist view, see generally DARON ACEMOGLU & JAMES A. ROBINSON, WHY NATIONS FAIL: THE ORIGINS OF POWER, PROSPERITY, AND POVERTY (2012).

38. Rochelle Cooper Dreyfuss, *Tailoring Incentives: A Comment on Hemel and Ouellette's* Beyond the Patents-Prizes Debate, 92 TEX. L. REV. 131, 132 (2014).

39. Amy Kapczynski, *The Cost of Price: Why and How to Get Beyond Intellectual Property Internalism*, 59 UCLA L. REV. 970, 985 (2012).

40. Daniel J. Hemel & Lisa Larrimore Ouellette, *Innovation Policy Pluralism*, 128 YALE L.J. 544, 547-50 (2019).

types) requires a comprehensive, complicated 'mix' of federal institutions."[41] Still, finding the ideal mix for a given innovation context requires that we know something about the differences between innovation levers and their relative strengths. For this, we must turn to comparative analysis.

A. Comparative Innovation Institutions

Analysts have differed in their preferred taxonomy of innovation funding mechanisms.[42] I will limit my comparative analysis here to four innovation levers: patents, prizes, tax incentives, and grants. This list is nonexhaustive. While I recognize the intellectual appeal and strong policy justifications for other levers, I focus on the four that are generally most prominent in the literature comparing different innovation institutions in law and policy.[43] Patents and grants are by far the two most important levers in practice. The patent system is the de facto innovation incentive structure in the law and, at least in theory, generates the lion's share of private R&D in the national economy, while the federal grant system represents the primary alternative (or complementary) way in which innovation is funded. R&D tax credits are another significant part of the federal government's innovation policy. The prize system plays a minimal, perhaps even negligible, role in practice, and I only include it here due to its importance in long-running scholarly debates.

Innovation institutions can be compared along any number of dimensions. The analysis that follows adapts the framework developed by Hemel and Ouellette in their work comparing patents, prizes, grants, and tax incentives. Hemel and Ouellette focus on three basic design choices: (1) who selects and sets a value for the R&D project; (2) when the reward is given to the innovator; and (3) who pays for that reward.[44] By disassembling these levers into their constitutive institutional-design choices, Hemel and Ouellette show that "innovation incentives fall onto a spectrum rather than into discrete boxes."[45] One way of describing this spectrum at a higher level of abstraction might be the extent to which the government or the market controls the innovation process and assumes its risks. Among the four levers that follow, patents are at the market-led end of this

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41. Brett Frischmann, *Innovation and Institutions: Rethinking the Economics of U.S. Science and Technology Policy*, 24 VT. L. REV. 347, 350 (2000).

42. *See* Joshua D. Sarnoff, *Government Choices in Innovation Funding (with Reference to Climate Change)*, 62 EMORY L.J. 1087, 1116-17 (2013) (discussing the many different taxonomies of innovation funding mechanisms offered by both legal scholars and economists).

43. *See, e.g.*, Hemel & Ouellette, *supra* note 18, at 307 (identifying patents, prizes, tax incentives, and grants as the "four main policy tools for promoting R&D").

44. *Id.* at 308-09.

45. *Id.*

spectrum, and grants at the other. As I discuss in the following Section, government research is one step even further toward a government-led system.

In theory, we can deduce from each innovation lever's institutional makeup some general comparative advantages offered by each. We might consider what kinds of innovations each lever can most efficiently incentivize, examining, for example, where on the technology-readiness spectrum the innovation falls. These would all remain somewhat speculative generalizations, however. Due to the heterogeneous nature of innovation, "grand theories are unlikely to be sufficiently context-sensitive," as Brett Frischmann and Mark P. McKenna note.[46] Empirical quantitative and qualitative analyses—with the latter including case studies—may be more instructive.

1. *Patents*

The patent system offers time-limited monopoly rights to innovators whose inventions meet a series of legal standards administered by the government. Except for some carveouts designating certain areas of nonpatentable subject matter, the tests for patentability are generally neutral across technological fields.[47] Aside from the government's minimal role in examining patent applications and enforcing patent rights through the courts, the patent system is an entirely market-driven process. Private actors choose which R&D projects to pursue and what resources to devote to them. Since only successful projects—and only those that meet baseline standards for patentable inventions—receive patent protection, private actors assume the risk that their efforts may be wasted. Projects can always fail, or R&D performers can lose out to rivals who were able to reduce the same invention to practice sooner.[48]

Patents solve what is believed to be the central obstacle to innovation in the absence of proprietary rights to ideas, known as the "appropriability problem": innovators who cannot protect their inventions from free riders cannot appropriate enough of a return to justify the up-front investments that led to those inventions and are thus generally disincentivized from pursuing innovation in the first place. Patents provide innovators with the right to exclude others from practicing their inventions during a twenty-year period. During that time, a patent holder can charge a supracompetitive price for the use of the invention at

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46. Frischmann & McKenna, *supra* note 16, at 316.

47. *But see generally* Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575 (2003) (arguing that patent-law doctrine actually does favor certain technological fields over others by virtue of the different ways in which the tests of patentability are applied to technologies in those fields).

48. This is known in the IP literature as "racing." *See, e.g.*, SUZANNE SCOTCHMER, INNOVATION AND INCENTIVES 46 (2004) (explaining this concept).

whatever the market will bear. That price ultimately determines the total size of the innovator's reward.

Economists have suggested that the primary comparative advantage of the patent system lies in "ex ante researcher information relating to the value of the invention."[49] As Nancy Gallini and Suzanne Scotchmer have noted, patents are justified when—and perhaps *only* when—there is "some type of asymmetric information about the costs and benefits of research programs," with the private sector having more information.[50] The potential for future patents can lead firms on a search for useful innovations, and patents themselves help put a value on those innovations after the fact. All of this is done by decentralized actors in the marketplace, which is generally thought to be a better aggregator of information than a single centralized entity, such as a government agency. The ex post basis of the reward is likewise thought to be advantageous since it provides researchers with "strong incentives to self-select projects with the best prospects for success as useable products."[51]

2. *Prizes*

Prizes are another form of ex post reward, where the government plays a more prominent role compared to the patent system. A prize system incentivizes innovation by offering direct monetary rewards to R&D performers for achieving specific goals.[52] Unlike in the patent system, the government selects and sets the value of projects it wishes to incentivize. Successful innovators receive prize money instead of proprietary rights, and the resulting innovations are usually made available in the public domain.[53] The private sector performs the R&D, using its resources and expertise to compete for the prize. The private sector also assumes the risk of failure, investing in research that may yield no reward if the solution criteria are not met or if competitors win.[54] Prizes thus operate, like patents, on an ex post basis: innovators only receive the prize if the project is

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49. Brian D. Wright, *The Economics of Invention Incentives: Patents, Prizes, and Research Contracts*, 73 AM. ECON. REV. 691, 703 (1983).

50. Gallini & Scotchmer, *supra* note 16, at 54.

51. Hemel & Ouellette, *supra* note 18, at 334 (quoting Rachel Glennerster, Michael Kremer & Heidi Williams, *Creating Markets for Vaccines*, INNOVATIONS: TECH., GOVERNANCE, GLOBALIZATION, Winter 2006, at 67, 71).

52. *See* SCOTCHMER, *supra* note 48, at 41.

53. *See* Abramowicz, *supra* note 17, at 119; Burstein & Murray, *supra* note 17, at 410.

54. *See* Roin, *supra* note 17, at 1018.

successful. This lowers the public sector's financial exposure and shifts risk to the R&D performers.[55]

Prizes are a good alternative to patents for technological areas where social benefits are high, but market incentives are lacking, a problem usually identified as a form of "market failure." For example, a prize might be a preferable incentive for a vaccine directed toward a disease afflicting people who would not be able to pay patent-protected prices for that drug. In this example, the concern over information asymmetry would also be minimal: all the government has to know is that a disease exists and that a vaccine might be possible to develop. The rest is left to private actors to develop research plans and carry them out.

3. *Tax Incentives*

R&D tax credits work to incentivize innovation by allowing firms to write off "qualified research expenses," essentially derisking private R&D efforts.[56] The government does not, for the most part, limit tax incentives to certain technologies or even certain fields; the private-sector performer of R&D decides what projects to pursue and how much to invest in them. Since the projects need not be successful to receive the write-off, the reward (the write-off itself) is given to the innovator on an ex ante basis.

Hemel and Ouellette note that tax incentives share with patents the advantage of leveraging ex ante private information. R&D tax credits establish "ground rules that are broadly applicable to most technologies" and "rely on potential innovators—rather than government officials—to decide (1) which inventions are worth pursuing and (2) which R&D projects are most likely to yield the inventions in question."[57] They allow competing R&D performers to work on the same project, since there is no limit to how many firms can make use of these credits. Hemel and Ouellette also suggest that tax credits offer an advantage to innovators who would struggle to raise the up-front investment necessary to compete for an ex post reward like a patent or prize.[58] The more secure and immediate reward provided by tax incentives allows the low-capital innovator to begin work sooner.

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55. Burstein & Murray, *supra* note 17, at 410.

56. Hemel & Ouellette, *supra* note 18, at 323-24.

57. *Id.* at 328.

58. *Id.* at 336.

4. *Grants*

Government grants represent an alternative lever that differs markedly from patents, prizes, and tax incentives. Grants are "[g]overnment-set" transfers that support research performed by private or nonprofit performers.[59] The grant system is a sprawling public-private complex that connects the state, industry, and academia to conduct a substantial portion of the national R&D effort. As with prizes, reward size in the grant system—the amount of funding awarded to the researcher—is set by the government. Grants are also paid for with public resources derived from the tax take. Grants' distinction from prizes is their reward structure: the reward is issued on an ex ante basis in order to "reimburse costs before they are incurred" by the research performer.[60] Grants are, therefore, in some sense "not a reward for success" in the manner of patents and prizes; the reward is issued whether or not the research is actually successful.[61] And, unlike in the prize system, issuing a grant requires the government to decide what projects to pursue and "whom to hire."[62] Grant-doling agencies have to identify not just promising projects but also the most promising means of undertaking them.

The grant system has been consistently portrayed in the innovation-law literature as a necessary evil: grants help deliver socially desirable innovation that the private sector is unable or unwilling to produce—like a prize system. However, grants are often seen as a "blunt tool" that comes with inefficient government bureaucracy, mismatched incentives, and problematic distributions of risk.[63] Grant-doling agencies are thought to be less effective than the market at processing information to select and assign value to R&D projects, a shortcoming derived from limited state capacity,[64] economic logic, or both. Since these rewards are ex ante, "the possibility of shirking also arises": researchers can secure funding for a project and then perform poorly or otherwise mismanage that funding.[65]

In his analysis of grants as a lever of innovation, W. Nicholson Price II has offered a corrective to this narrative. Using the NIH extramural program as a case study, Price details the nuanced mechanisms through which the grant

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59. *Id.* at 327-28 (describing grants as "[g]overnment-set" transfers as opposed to market-led mechanisms of the patent system or tax incentives).

60. SCOTCHMER, *supra* note 48, at 247.

61. *Id.*

62. Kapczynski, *supra* note 39, at 986.

63. Price, *supra* note 19, at 9-16.

64. Hemel and Ouellette note the risks of "politicization, rent-seeking, and mismanagement" in government-set rewards such as grants. Hemel & Ouellette, *supra* note 18, at 327.

65. Kapczynski, *supra* note 39, at 986.

system aggregates information in project selection and incentivizes high-quality work by research performers.[66] Price shows that the project-selection process is far from an inefficient system of "central planning" by insulated bureaucrats and instead relies on a decentralized process of applicant-driven proposals judged by external reviewers.[67] Researchers are held accountable by direct monitoring and by the underlying incentive to perform well in order to secure future grants, which can make or break careers.[68] Price's key insight is that even though the government does select projects, and rewards are given ex ante, how this selection and reward process is carried out matters. As I discuss in the following Sections, the intramural system has comparable but distinct mechanisms for selecting promising projects and ensuring strong performance.

B. Government Research in the Innovation-Law Literature

Government research rarely appears in innovation-law scholarship. When it has, it is often collapsed into the same category as grants,[69] or summarily described as "different" with limited further examination of these unique features.[70] The lacking treatment of intramural research as an innovation lever is likely a symptom of the field's near-exclusive focus on IP-based knowledge production. If until recently the grant system has sat on the fringes of innovation-law scholarship, government research has been off in the woods beyond. My task here is thus different from Price's vis-à-vis grants: there are no real myths to

66. *See* Price, *supra* note 19, at 17-41, 50-59.

67. *See id.* at 20-32.

68. *See id.* at 32-37. Scotchmer makes a similar point about repeat players, noting that "only the more productive researchers . . . will stay in the system, and to stay in the system, they must perform." SCOTCHMER, *supra* note 48, at 250.

69. *See, e.g.*, Hemel & Ouellette, *supra* note 18, at 320 (identifying the innovation mechanism "[g]overnment [g]rants" as "a category that includes direct spending on government research laboratories and grants to nongovernment researchers"); *see also* Frischmann, *supra* note 41, at 386-87 (describing the situation in which the government "conducts the research itself, for example, through government laboratories" as a form of "direct subsidization" through a government grant); Kapczynski, *supra* note 39, at 972 (describing the entirety of the government's effort to support R&D across the nation as "government contracting," in which "government agencies make grants or contract for research"). Kapczynski acknowledges later in a footnote, however, that "[the] government can also conduct research itself, rather than contracting it out" and notes that "this possibility has received little focus in the economics literature." Kapczynski, *supra* note 39, at 983 n.42.

70. *See, e.g.*, Price, *supra* note 19, at 17 (noting, in a larger discussion about grants, that "[t]he government may also directly conduct intramural research by employing scientists at, for instance, National Laboratories or laboratories at the NIH or the Centers for Disease Control and Prevention").

dispel about government research in the innovation-law literature because there is practically no discussion of it at all.

Only two legal scholars have discussed intramural research as a potentially distinct innovation lever. Joshua D. Sarnoff, in his appeal for a better-informed assessment of federal innovation-policy choices, labels intramural work "direct development" and notes a few basic features that may set it apart from other forms of knowledge production: field-specific expertise, government-owned IP, and collaborations with outside partners.[71] Sarnoff notes the potential for government employment to be seen as less appealing than industry or academic positions, but cautions that "the government should not be routinely dismissed as an innovation funding choice" and calls for "additional study of the relative efficiency and effectiveness of [government research] compared to private-sector funding options."[72] This study responds to Sarnoff's call for a deeper analysis.

Rochelle Cooper Dreyfuss, in her response to Hemel and Ouellette's work on comparative innovation institutions, also raises the possibility that intramural R&D may be a distinct paradigm.[73] Using pharmaceutical innovation as an example, Dreyfuss suggests that government researchers can serve as "honest brokers," unbiased by the profit motive in reporting the safety and efficacy of a drug developed in the course of intramural work and in developing diagnostic tests.[74] Government research might also, in Dreyfuss's view, be used to address the "valley of death" that separates basic biomedical research from commercializable pharmaceutical products by doing work that "other innovators find impossible to undertake."[75] I examine how exactly government research fits into the innovation system—and what it can do that others find impossible—in my analysis below. Finally, Dreyfuss also notes the unique "learning dimensions" that government research involves.[76] Scientists working for the government can create "a learning opportunity for society as a whole" by serving as experts on behalf of the public interest.[77] This is an element of state capacity, a broader advantage of government research as an innovation lever to which I will return later.

Outside of legal scholarship, economic sociologists have offered some of the most in-depth analyses of the workings of the federal research system. But the unit of analysis of these studies tends to be either the national innovation system

71. Sarnoff, *supra* note 42, at 1132-36.

72. *Id.* at 1136.

73. Dreyfuss, *supra* note 38, at 132-34.

74. *Id.* at 132-33.

75. *Id.* at 134.

76. *Id.* at 136.

77. *Id.*

as a whole[78] or individual programs,[79] usually over a given period. Sociologists' emphasis on networks is instructive for understanding how the innovation process plays out in these settings, but it elides some critical differences between institutions within the innovation state. A sociological perspective would, for example, frame extramural and intramural research as fundamentally the same type of thing: state-led maintenance of innovation networks that the market alone fails to cultivate.[80] Legal scholarship can instead offer a focus on specific incentives and institutional design, and on the practical and normative implications that flow from those design choices.[81]

At first glance, intramural R&D indeed appears very similar to the grant system in its institutional design: the government chooses which projects to support and at what level of funding; resources are committed before the completion of projects; and the whole system is cross-subsidized through the taxpayer-funded government budget. The manifest difference is that the performer of intramural research is the government itself—usually a team of government-employed researchers. Price's reassurances about the grant system are largely based on the institutional separation between government funder and private or nonprofit performer, wherein granting agencies like the NIH turn to applicants for proposals and external experts for peer review, and grantees keep to a high standard because they want to secure more grants in the future.[82] But there is no such separation in intramural R&D, and as Suzanne Scotchmer points out, "[i]t is much harder to fire an employee than to turn down a grant proposal."[83]

78. *See generally* STATE OF INNOVATION: THE U.S. GOVERNMENT'S ROLE IN TECHNOLOGY DEVELOPMENT (Fred Block & Matthew R. Keller eds., 2011) (describing the role of the federal government in technology innovation).

79. *See, e.g.*, Matthew R. Keller, *The CIA's Pioneering Role in Public Venture Capital Initiatives*, *in* STATE OF INNOVATION, *supra* note 78, at 109, 109-33 (describing the phenomenon of public venture-capital initiatives); Andrew Schrank, *Green Capitalists in a Purple State: Sandia National Laboratories and the Renewable Energy Industry in New Mexico*, *in* STATE OF INNOVATION, *supra* note 78, at 96, 96-108 (describing the emergence of New Mexico's renewable-energy cluster as a consequence of federal science policy).

80. *See generally, e.g.*, Matthew R. Keller & Marian Negoita, *Correcting Network Failures: The Evolution of U.S. Innovation Policy in the Wind and Advanced Battery Industries*, 17 COMPETITION & CHANGE 319 (2013) (illustrating the emphasis by sociologists interested in state-led innovation on networks as the key focus of analysis).

81. Frischmann & McKenna, *supra* note 16, at 323 ("Legal scholars are well-suited to engage in descriptive analyses of legal frameworks and prescriptive analyses of institutional designs given existing legal frameworks and some external normative objective. A lawyer's expertise is, after all, institutional design.").

82. *See supra* notes 66-68 and accompanying text.

83. SCOTCHMER, *supra* note 48, at 248. I argue in Section IV.A.3 below that funding stability is actually an advantage of intramural R&D because it tends to support higher-risk research.

We can therefore add to Hemel and Ouellette's three key attributes for comparative analysis ("*who decides*, *when* does the transfer occur, and *who pays*"[84]) a fourth: *who performs the R&D*. This will be either the government itself or a non-government actor, usually a firm or university research group. The following Table summarizes the key institutional-design choices discussed thus far for the four levers of innovation, with the addition of government research:

TABLE 1. INNOVATION LEVERS AND INSTITUTIONAL-DESIGN CHOICES[85]

	Project Selection and Valuation	Reward Timing	Subsidization	R&D Performer
Patents	Market	Ex post	Market	Industry / nonprofit
Prizes	Government	Ex post	Government	Industry / nonprofit
Tax Incentives	Market	Ex ante	Government	Industry / nonprofit
Grants	Government	Ex ante	Government	Industry / nonprofit
Government Research	Government	Ex ante	Government	Government

The concerns about the grant system that Price aims to dispel would thus seem to apply even more forcefully to government research. Based on institutional design alone, government research might seem like a bad idea. Unflattering characterizations of this institutional design are easy to conjure: *government bureaucrats giving themselves taxpayer-funded money up front for R&D projects that they themselves select*. But as Price has shown in his closer look at the grant system, the details matter. How does government research actually work as a lever of innovation? What goes on behind the curtain—or in this case, the laboratory door? How are decisions made in the research process, and what incentives are

84. Hemel & Ouellette, *supra* note 18, at 308.

85. This is an adaptation of Figure 2 from Hemel and Ouellette. *Id.* at 348 fig.2. Note that these are merely the paradigmatic or standard versions of each of these innovation levers. As Hemel and Ouellette suggest, we can imagine variations of each that flip certain design choices and thus result in quite different levers. *Id.* at 348-49. For example, the government could offer tax incentives only for a specified technological area or even for a specific invention that has not yet been reduced to practice. This would mean that the government, rather than the market, would be deciding on the project.

there to encourage strong performance without the "repeat-player" solution of the grant system? What is the role of government research in the national innovation system more generally? To answer these questions, we must go beyond basic institutional architecture and look closely at government research in practice.

II. GOVERNMENT RESEARCH IN PRACTICE

The Sections that follow examine government research in practice from multiple perspectives. The first is historical. By looking at when and where government research came from, we can gain insight into its original purpose and how that purpose may have evolved over time. Second, we can examine the contemporary system of government research, focusing on the overall size of intramural programs in the federal R&D system and how they are organized. Third, and most importantly for this analysis, we can take a detailed, on-the-ground look at how research is actually carried out in intramural programs. From those details, we can abstract general principles on the nature and function of intramural work as an innovation lever.

A. Overview

1. Historical Background

The emergence of the federal government as the nation's leading sponsor of R&D in the twentieth century is a story that has been told many times.[86] The

86. *See, e.g.*, DANIEL LEE KLEINMAN, POLITICS ON THE ENDLESS FRONTIER: POSTWAR RESEARCH POLICY IN THE UNITED STATES 52-100 (1995); JONATHAN GRUBER & SIMON JOHNSON, JUMP-STARTING AMERICA: HOW BREAKTHROUGH SCIENCE CAN REVIVE ECONOMIC GROWTH AND THE AMERICAN DREAM 1-8 (2019); DAVID C. MOWERY, RICHARD R. NELSON, BHAVEN N. SAMPAT & ARVIDS A. ZIEDONIS, IVORY TOWER AND INDUSTRIAL INNOVATION: UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER BEFORE AND AFTER THE BAYH-DOLE ACT 21-27 (2004); Fred Block, *Innovation and the Invisible Hand of Government*, *in* STATE OF INNOVATION, *supra* note 78, at 1, 6-14; DANIEL J. KEVLES, THE PHYSICISTS: THE HISTORY OF A SCIENTIFIC COMMUNITY IN MODERN AMERICA 324-92 (1978); G. PASCAL ZACHARY, ENDLESS FRONTIER: VANNEVAR BUSH, ENGINEER OF THE AMERICAN CENTURY 222-44 (1997); MARIANA MAZZUCATO, THE ENTREPRENEURIAL STATE: DEBUNKING PUBLIC VS. PRIVATE SECTOR MYTHS 73-86 (2013). *But see* DAVID M. HART, FORGED CONSENSUS: SCIENCE, TECHNOLOGY, AND ECONOMIC POLICY IN THE UNITED STATES, 1921-1953, at ix (1998) (downplaying Bush's interventions as a "creation myth" and arguing instead that postwar science policy emerged from a combination of competing reform traditions); WALTER A. MCDOUGALL, . . . THE HEAVENS AND THE EARTH: A POLITICAL HISTORY OF THE SPACE AGE 7-10 (1985) (arguing instead that the moment of institutional discontinuity was the late 1950s following Russia's launch of the Sputnik satellite).

canonical narrative runs as follows. Prior to the Second World War, the federal government played a minimal role in supporting science and technology development; these fields relied instead on corporate research and university science funded primarily through philanthropy. The outbreak of the war spurred the federal government into action and marked a rupture in the political economy of American science. The state's new capacities for effectively supporting and organizing R&D, led by scientist-administrator-entrepreneur Vannevar Bush and based primarily on research contractors, were firmly established by the United States's wartime technological dominance. In the immediate postwar period, Bush lobbied successfully for the peacetime extension of the institutional approach he had pioneered during the war: the federal government would be the nation's leading sponsor of research, but it would rely primarily on university and industry contractors to perform that research. The rest of this story—seventy years at this point—is one government-funded but contractor-developed breakthrough after another.

It is not my aim to dislodge this narrative but to complicate it. If our focus is the development of the grant system, then surely World War II was the turning point and Bush the protagonist. If, however, we focus on intramural research, the story is perhaps a more continuous one than is typically portrayed.[87] From the early republic to today, government research figures prominently in the state's efforts to promote science and technology in furtherance of national goals. Arguably, the first of these efforts was the early-nineteenth-century exploratory missions that aimed to catalog the landscape of western territories and prepare the way for further colonial expansion into Native lands.[88] While most of this activity was ad hoc, some permanent government research agencies—primarily housed within the military—began to emerge by the middle of the nineteenth century.[89] Government research expanded following the Civil War; new institutions included the federal government's "labs without walls," such as the U.S.

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87. The case for continuity was made by A. Hunter Dupree in his seminal review of the relationship between the federal government and science from the Founding to the outbreak of World War II. *See* A. HUNTER DUPREE, SCIENCE IN THE FEDERAL GOVERNMENT: A HISTORY OF POLICIES AND ACTIVITIES TO 1940, at 1-3 (1957). Dupree, however, was writing in the early 1950s, before the full implications of the dramatic increase in federal funding and the expansion of the grant system could be absorbed.

88. The first and most famous of these was the expedition of Lewis and Clark, organized by the Jefferson Administration. *Id.* at 24-33.

89. The most significant example is the Naval Observatory, founded in 1842. *Id.* at 61-65.

Geological Survey (1879), which now forms the intramural research arm of the Department of the Interior.[90]

By the turn of the century, the Department of Agriculture had become the institutional capital of government research, housing the Biological Survey (1885) as well as the Federal Bureaus of Animal Industry (1884), Chemistry (1901), Plant Industry (1901), and Soils (1901).[91] These institutions performed what would now be recognized as applied research to solve technical problems facing U.S. agriculture, such as animal diseases.[92] As historian Hunter Dupree notes, the emerging "Bureau System" organized research in ways that resonate strikingly with contemporary government research programs:

> [T]he ideal scientific bureau had clearly defined characteristics. In the first place, the center of its interest was a problem, not a scientific discipline. Instead of a chemist who tested both fruits and fertilizers, the problems of growing particular crops or improving animals became central, and the bureau mobilized teams of experts from various disciplines to attack each one. Such an approach required on the one hand stability to concentrate on a given line of investigation over a period of years, and on the other hand the flexibility to shift resources as the problem changed.[93]

Federal research continued to expand in the first few decades of the century with new agencies like the National Bureau of Standards (1901), the precursor to the Commerce Department's National Institute of Standards and Technology, and the National Advisory Committee for Aeronautics (1915), which would later become the National Aeronautics and Space Administration (NASA).[94] Roosevelt's New Deal sought to mobilize government R&D in service of economic recovery and development, most famously through the Tennessee Valley Authority (1933).[95] At the start of the Second World War, there were already over forty scientific agencies in the federal government performing research, and intramural R&D constituted a substantial portion of national R&D expenditures, public

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90. The author thanks Daniel Kevles for the phrase "labs without walls." The U.S. Geological Survey was established in 1879. Mary C. Rabbitt, *The United States Geological Survey: 1879-1989*, U.S. GEOLOGICAL SURV. 1 (1989), https://pubs.usgs.gov/circ/1050/pdf/CIRC1050.pdf [https://perma.cc/TZ4T-TGLW].

91. DUPREE, *supra* note 87, at 158-69, 385.

92. *Id.*

93. *Id.* at 158.

94. *Id.* at 385.

95. *Id.* at 362-63.

and private sources included.[96] Along with patents, government research was the primary tool through which the federal government supported science and technology development.

As economists David C. Mowery and Nathan Rosenberg have noted, wartime mobilization elevated two very different institutional models of government support for R&D.[97] The first was Vannevar Bush's Office of Scientific Research and Development, which contracted out projects to a growing network of industrial and academic labs and would eventually serve as the model for the expanded grant system in the postwar period.[98] The second, however, was the Manhattan Project, a dramatic intensification and scaling up of the intramural approach that had long been a feature of the government's arsenal.[99] The crash program, ending with the bombings at Hiroshima and Nagasaki, proved that the federal government could commit massive resources to complex technological problems in the national interest and achieve quick, if in this case devastating, results. This became the model for the national labs and other large-scale postwar intramural programs.[100] World War II thus gave rise to the modern

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96. The number of government research sites was noted by Vannevar Bush himself in his famous tract, *Science: The Endless Frontier*, which advocated for a centralized grant-doling agency that eventually became the National Science Foundation (NSF). VANNEVAR BUSH, SCIENCE: THE ENDLESS FRONTIER 9, 11 (1945). The only reliable prewar estimates of public and private research expenditures come from the National Resources Planning Board (NRPB), a New Deal-era statistics-and-economic-planning office housed in the White House. The NRPB estimated in 1938 that government R&D expenditures (most of which would have funded intramural work at that time) exceeded private R&D outlays by twenty percent. *See* 1 NAT'L RES. COMM., RESEARCH: A NATIONAL RESOURCE 8 (1938). Viewed in this light, analyses of federal innovation policy that minimize the government's prewar role are somewhat misleading. *E.g.*, SCOTCHMER, *supra* note 48, at 240 ("Before World War II, R&D funding by the federal government was a small percentage of total R&D, and what existed was mostly intramural.").

97. DAVID C. MOWERY & NATHAN ROSENBERG, TECHNOLOGY AND THE PURSUIT OF ECONOMIC GROWTH 124-25 (1989).

98. *Id.* For a recent review of the Office of Scientific Research and Development (OSRD) as a "crisis innovation model" and its technological successes, see Daniel P. Gross & Bhaven N. Sampat, *The World War II Crisis Innovation Model: What Was It, and Where Does it Apply?*, 52 RSCH. POL'Y art. no. 104845, at 2 (2023). Gross and Sampat also distinguish the OSRD model from the Manhattan Project. Gross & Sampat, *supra*, at 14.

99. Gross & Sampat, *supra* note 98, at 4, 7. Tellingly, the Manhattan Project began as an OSRD grant-supported program reliant on contractors, but it was transferred to the Army once the project was determined to be too large for contractors alone and in need of a clearer and more effective chain of command. *See* RICHARD RHODES, THE MAKING OF THE ATOMIC BOMB 423-24 (1986). The switch actually illustrates, in no small way, some of the differences between government research and the grant system that are further discussed in Section III.A, *infra*.

100. *Origins*, U.S. DEP'T ENERGY, https://www.energy.gov/science/history [https://perma.cc/4RNJ-8YU9].

research-grant system while also expanding the already substantial role of government research.

The impacts of federal research programs on the national economy escape reliable quantitative measures.[101] However, a qualitative look at the historical record reveals a litany of achievements by the intramural system in the postwar era. The NIH's Intramural Research Program (IRP) pioneered countless breakthroughs, both in fundamental science and in applied clinical fields.[102] The successes of intramural work at NASA in the 1960s and 1970s still mark the high point of postwar "giant leaps" in technological capacity.[103] The achievements of the national labs are especially noteworthy. As recent work from Fred Block, Matthew R. Keller, and Marian Negoita shows, between 1999 and 2019, one-third of all "R&D 100" awards—the most prominent annual international science-and-technology awards contest—were for breakthroughs at the national labs.[104] If we were to include the Manhattan Project itself in the list, the national labs have employed seventy-two Nobel Prize winners at some point in their careers.[105]

2. *The Contemporary System*

The federal R&D landscape today reflects the dual institutional tradition as it has evolved in the postwar era. In 2022, the federal government doled out just

101. There have been a number of attempts to quantitatively evaluate the impact of federal R&D spending, but each approach has serious limitations. *See* Adam B. Jaffe, *Analysis of Public Research, Industrial R&D, and Commercial Innovation*, *in* THE SCIENCE OF SCIENCE POLICY: A HANDBOOK 193, 193 (Julia I. Lane, Kaye Husbands Fealing, John H. Marburger III & Stephanie S. Shipp eds., 2011) (suggesting that the aggregate social returns rather than the private returns to innovation spending are difficult to measure); *see also* E.J. Reedy, Michael S. Teitelbaum & Robert E. Litan, *The Current State of Data on the Science and Engineering Workforce, Entrepreneurship, and Innovation in the United States*, *in* THE SCIENCE OF SCIENCE POLICY, *supra*, at 208, 208 (pointing out the limitations of data that focus on the principal investigator or research lab as the unit of analysis and ignore other roles); STATE OF INNOVATION, *supra* note 78, at 149 (pointing out the unreliability of traditional measures of research success such as patents and academic citations).

102. *See* Intramural Rsch. Program, *Accomplishments by Date*, NAT'L INSTS. HEALTH (Jan. 14, 2022), https://irp.nih.gov/accomplishments/accomplishments-by-date [https://perma.cc/6KMS-53W7] (listing the NIH IRP's major scientific achievements from 1951 to 2024).

103. *60 Moments in NASA History*, NAT'L AERONAUTICS & SPACE ADMIN., https://www.nasa.gov/specials/timeline [https://perma.cc/VK3G-E74Z] (reviewing landmark achievements from 1958 to 2018).

104. Fred Block, Matthew R. Keller & Marian Negoita, *Revisiting the Hidden Developmental State*, 52 POL. & SOC'Y 208, 214 (2023).

105. Off. of Sci., *DOE Nobel Laureates*, U.S. DEP'T ENERGY, https://science.osti.gov/About/Honors-and-Awards/DOE-Nobel-Laureates [https://perma.cc/79AY-UWUT].

over $190 billion for R&D, and $86 billion of that total was spent on intramural research (or just over 45%).[106] The remaining $104 billion went toward extramural research in a variety of forms: R&D grants were awarded to industry research performers ($50 billion), universities ($42 billion), nonprofit organizations ($10 billion), and state and local governments ($925 million).[107] A smaller portion of the extramural total was given to non-U.S. R&D performers ($818 million).[108] These figures reflect a roughly equal division in federal R&D obligations between intramural and extramural support. If, however, we divide up these totals by the entity conducting this research, then government-conducted research is by far the largest category of R&D in the federal research system, with grant-supported industrial research as a distant second.

It is likely impossible to determine accurately the amount of R&D performed in the national economy that would not be undertaken absent a patent system—in other words, how much R&D patents generate. Recent estimates released by the National Science Foundation (NSF) put total private R&D spending well above $700 billion, though that sum heavily favors later-stage experimentation and commercial development.[109] This is consistent with Hemel and Ouellette's analysis, since much private R&D is performed without the expectation of a patent.[110] Hemel and Ouellette estimate that $10 billion is "spent" by the government each year in the form of R&D tax credits as forgone tax revenue.[111] The national prize system is nearly nonexistent in comparison, with less than $100 million spent each year on public or privately supported prizes.[112] While the

106. These numbers are the most recent made available by the NSF. Nat'l Ctr. for Sci. & Eng'g Stat., *Federal Funds for Research and Development: Fiscal Years 2022–23*, NAT'L SCI. FOUND. tbl.7 (Apr. 3, 2024), https://ncses.nsf.gov/pubs/nsf24321/table/7 [https://perma.cc/9KCP-72ZP]. The $86 billion figure is the sum of the third and fourth columns—"federal agencies" and "FFRDCs"—for "all agencies," both classified as "intramural" research. This figure may be unusually high due to COVID-19-related spending at the Biomedical Advanced Research and Development Authority (BARDA), an intramural unit within the Department of Health and Human Services that led the federal government's initiatives for vaccine development and rollout. However, even after removing BARDA's allocation from the data, intramural research remains the largest category by specific performer type.

107. *Id.* It may come as a surprise to some that the grant system supports far more research in private industry.

108. *Id.*

109. Nat'l Ctr. for Sci. & Eng'g Stat., *supra* note 23. Hemel and Ouellette have estimated that the government spends somewhere between $30 billion and $700 billion dollars per year in the form of a "shadow sales tax" caused by patent-enabled supracompetitive prices. Hemel & Ouellette, *supra* note 18, at 361.

110. Firms may conduct R&D and seek to protect their results with trade secrets, for example. They may also conduct R&D and make their results available in an open-source fashion.

111. Hemel & Ouellette, *supra* note 18, at 361.

112. *Id.*

broader national R&D effort is driven in large part by private spending in the shadow of IP incentives, government research still figures prominently in comparison.

These aggregate figures may obscure even more substantial roles for government research in particular industries, especially those still in their infancy. Consider, for example, the aerospace subsector devoted to spacecraft and rocket science. Historically, NASA was the only game in town. For decades, this sector—to the extent that it could even be considered a "sector" without a commercial market—was almost purely the product of government research. Today, this is no longer true, with the arrival of several private spacecraft manufacturers and launch-service providers, including Elon Musk's SpaceX and Jeff Bezos's Blue Origin. Despite the chorus of enthusiasm for this emerging industry, government research at NASA still dominates the sector: in 2022, SpaceX led its private-sector peers with $1.3 billion spent on R&D, a figure dwarfed by NASA's R&D budget of over $12 billion.[113] Other frontier industries are likely to follow a similar pattern.[114]

Two institutional models predominate in the government research system: (1) intramural agency research and (2) research carried out at federally funded R&D centers (FFRDCs). Intramural agency research is conducted by civil-servant scientists working for an in-house research program at a federal agency. Prominent examples include the NIH IRP, the Department of Agriculture's Agricultural Research Service, the Geological Survey, and the many in-house laboratories run by the six branches of the military.[115] Scientists at these sites are

113. Micah Maidenberg, Corrie Driebusch & Berber Jin, *A Rare Look into the Finances of Elon Musk's Secretive SpaceX*, WALL ST. J. (Aug. 17, 2023, 3:22 PM), https://www.wsj.com/tech/behind-the-curtain-of-elon-musks-secretive-spacex-revenue-growth-and-rising-costs-2c828e2b [https://perma.cc/3B36-8BW3]; *Fiscal Year 2022 Agency Financial Report*, NAT'L AERONAUTICS & SPACE ADMIN. 12 (Nov. 15, 2022), https://www.nasa.gov/wp-content/uploads/2023/11/fy2022-afr-version5-111522-c.pdf [https://perma.cc/P827-AJJY] (reporting $12.3 billion in R&D spending in fiscal year 2022).

114. This may include fusion-energy and quantum-computing research, both mainstays of federal intramural research housed primarily in the national laboratory system. Price points out that the biomedical field, by contrast, is dominated by grants rather than intramural research as a result of the NIH's preference for the former tool. Price, *supra* note 19, at 4.

115. The federal government does not maintain a list of active intramural agency programs or sites, but programs funded at over $500 million per year include: the NIH IRP; the Geological Survey; the Veterans Administration Office of Research and Development; intramural research at NASA; the Food and Drug Administration Intramural Program; BARDA; intramural programs within the Navy, Army, and Air Force; the National Oceanic and Atmospheric Administration; the National Institute of Standards and Technology; and the Agricultural Research Service. The single largest of these by average annual funding is the Navy's intramural program. *See* Nat'l Ctr. for Sci. & Eng'g Stat., *supra* note 106, tbl.7 (displaying the data, which can be found under the column header "Federal agencies").

federal government employees, and the facilities are all government-owned, government-operated (GOGO).

At FFRDCs, the physical research facilities are owned by the government, but the research programs themselves are run by contractors and researchers in their employ. Management contracts are usually five years or longer with the expectation of renewal. This is the government-owned, contractor-operated (GOCO) structure followed by FFRDCs like Lawrence Livermore National Laboratory (LLNL), NASA's Jet Propulsion Laboratory, the Treasury's Center for Enterprise Modernization, and many others.[116]

For the purposes of the foregoing analysis, I treat the GOGO and GOCO models of government research as fundamentally the same type of innovation institution. Though this may sacrifice some nuance, the two institutional-design choices are nearly equivalent in several key dimensions important for this analysis, including the nature of the research process, funding patterns, motivations for researchers, and the general niche both types of intramural research occupy in the national innovation system.[117] During the Biden Administration, the federal government itself endorsed this approach: the NSF's National Center for Science and Engineering Statistics (NCSES), the government's leading authority on R&D data, announced in early 2024 that it would henceforth collapse GOGO- and GOCO-driven research into a single category.[118] The NCSES made this shift because GOCO research programs are totally reliant on their federal sponsor, and they perform R&D "directed by federal agencies' needs and mission objectives" or efforts "similar to that of the federally administered laboratories."[119]

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116. Nat'l Ctr. for Sci. & Eng'g Stat., *Master Government List of Federally Funded R&D Centers*, NAT'L SCI. FOUND. (Feb. 2025), https://ncses.nsf.gov/resource/master-gov-lists-ffrdc [https://perma.cc/PSE8-HC6Y].

117. Future work might tease out the ways in which government-owned, contractor-operated (GOCO) intramural research differs from government-owned, government-operated (GOGO) intramural research. A recent online post from the National Energy Technology Laboratory notes that as the only GOGO national lab, it is set apart from the GOCO labs in the following ways: (1) serving as an "honest broker" of information for the public and government; (2) maintaining a fuller set of in-house managerial capacities; (3) managing both intramural and extramural research; (4) working better with government authorities to address national priorities; and (5) better engaging in extramural partnerships, including cooperative research and development agreements. It is not clear from the lab's statement, however, what about the GOGO model leads to these differences. Brian Anderson, *The NETL Unique Advantage of Being a Government-Owned, Government-Operated Laboratory*, NAT'L ENERGY TECH. LAB'Y (May 22, 2023), https://netl.doe.gov/node/12519 [https://perma.cc/8DBZ-RGZF].

118. Nat'l Ctr. for Sci. & Eng'g Stat., *Reclassification of Federally Funded Research and Development Centers as Federal Intramural Performers of R&D*, NAT'L SCI. FOUND. (Jan. 4, 2024), https://ncses.nsf.gov/pubs/nsf24312 [https://perma.cc/4XME-DYBU].

119. *Id.*

Government research is thus varied in institutional structure across different sites but ultimately similar enough to serve as a single target for analysis. To understand its workings requires moving beyond aggregate statistics to the details of particular case studies. Those details can then inform a reconstructed account of how this innovation lever actually works in practice.

B. Case Studies of Government Research Programs

While each intramural program is likely to have some peculiarities, the following two case studies were selected to be broadly representative of the two institutional models noted above. The NIH IRP is the largest and among the longest running of the federal government's intramural research programs. It has also served as a model for other federal research programs in the course of their development.[120] LLNL occupies a similar place in the FFRDC category, and many of the strategies pursued at the laboratory have been exported to other GOCO research sites. While some of the observations that follow may be program-specific, many are likely to be externally valid.

1. National Institutes of Health Intramural Research Program

a. Overview

The NIH has long been the "largest public funder of biomedical research in the world."[121] Headquartered in Bethesda, Maryland, and with a reach spanning the globe, the NIH currently commands an annual budget of just under $50 billion.[122] Of that total, nearly 83% is dedicated to extramural work, the majority of which supports biomedical research at universities.[123] In 2021, the NIH doled

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120. Intramural Rsch. Program, *History*, NAT'L INSTS. HEALTH (Jan. 10, 2022), https://irp.nih.gov/about-us/history [https://perma.cc/86QG-NNAD] ("Our model has been—and remains—an excellent one for other federal laboratories, research foundations, academic centers, and other governments that seek to establish research laboratories.").

121. *Grants & Funding*, NAT'L INSTS. HEALTH (Jan. 21, 2025), https://www.nih.gov/grants-funding [https://perma.cc/PLG7-P4V7].

122. *Budget*, NAT'L INSTS. HEALTH (June 13, 2025), https://www.nih.gov/about-nih/what-we-do/budget [https://perma.cc/B52C-D8LV]. Note that the second Trump Administration has requested a $20 billion cut to the NIH budget in 2026, a reduction that would radically transform and hamper the agency. Megan Molteni, Jonathan Wosen & Anil Oza, *Trump Budget Draft Proposes NIH Consolidation and 40% Spending Cut*, STAT (Apr. 16, 2025), https://www.statnews.com/2025/04/16/trump-draft-budget-proposes-nih-consolidation-40-percent-cut [https://perma.cc/S2RH-AHG3]. The congressional appropriations process for 2026 is ongoing at the time of writing.

123. *See Budget*, *supra* note 122.

out over $24 billion for university R&D, nearly two-thirds of the total support by the federal government for academic science in all fields.[124] The NIH is far and away the largest supporter of university research in the federal system, followed by the NSF and the military at a distant $5 billion each.[125] There is therefore no national institution more foundational to the academic grant system than the NIH, one reason why it is such a useful case study for analyzing the workings of extramural research.[126]

The NIH also serves as an illustrative example of how intramural research works. The NIH IRP is comprised of research laboratories run by government-employed principal investigators—approximately 1,200 in total—spanning a wide range of basic, translational, and clinical biomedical research.[127] The NIH is made up of twenty-seven distinct research institutes—hence, National *Institutes*—each with a unique scientific agenda or emphasis on a particular disease.[128] The IRP is the collective set of in-house research programs spread out across these twenty-seven institutes and centers.[129] With an annual budget of around $5 billion, the IRP is the largest performer of biomedical research in the world, if considered a single entity.[130] While there is meaningful variety in the organizational makeup and research strategy of the intramural programs at different

124. Nat'l Ctr. for Sci. & Eng'g Stat., *supra* note 23.

125. *Id.*

126. *See* Price, *supra* note 19, at 4.

127. Intramural Rsch. Program, *What is the IRP?*, NAT'L INSTS. HEALTH (Jan. 10, 2022), https://irp.nih.gov/about-us/what-is-the-irp [https://perma.cc/F77A-MG8D].

128. *See List of Institutes and Centers*, NAT'L INSTS. HEALTH (Jan. 15, 2025), https://www.nih.gov/institutes-nih/list-institutes-centers [https://perma.cc/QGV8-A298].

129. Four of the twenty-seven NIH institutes and centers do not house an IRP. The institutes that do include the National Cancer Institute (NCI), National Eye Institute, National Human Genome Research Institute, National Institute on Aging, National Institute of Alcohol Abuse and Alcoholism, National Institute of Allergy and Infectious Diseases, National Institute of Arthritis and Musculoskeletal and Skin Diseases, National Institute of Biomedical Imaging and Bioengineering, Eunice Kennedy Shriver National Institute of Child Health and Human Development, National Institute on Deafness and Other Communication Disorders, National Institute of Dental and Craniofacial Research, National Institute of Diabetes and Digestive and Kidney Diseases, National Institute on Drug Abuse, National Institute of Environmental Health Sciences, National Institute of Mental Health, National Institute of Minority Health and Health Disparities, National Institute of Neurological Disorders and Stroke, National Institute of Nursing Research, National Library of Medicine, NIH Clinical Center, National Center for Advancing Translational Sciences, National Center for Complementary and Integrative Health, and National Heart, Lung, and Blood Institute. Nina F. Schor, *The NIH Intramural Research Program: Opportunities for Training and Career Development in Neuroscience and Beyond*, 1 ANNALS CHILD NEUROLOGY SOC'Y 38, 39 (2023).

130. Intramural Rsch. Program, *supra* note 127.

institutes,[131] all IRP labs are organized under a GOGO structure, and enough is shared between them vis-à-vis institutional design to analyze the program as a whole.

The NIH began in 1887 as the "Hygienic Laboratory," a one-room and essentially one-man[132] intramural laboratory at the Marine Hospital on Staten Island tasked with investigating diseases affecting sailors.[133] At the turn of the century, Congress began to expand the scope and scale of the laboratory and relocated it to Washington, D.C.[134] Extramural support expanded dramatically during and after World War II, and new field-specific institutes proliferated.[135] At the same time, the NIH's in-house research activities were reconfigured to be more attractive to industry and academic scientists who were lured to Bethesda, the site of the new NIH headquarters, with promises of greater intellectual freedom and no teaching requirements.[136] The renamed Intramural Research Program took on some of the organizational forms that had been developed during a successful wartime research program focused on treatments for malaria.[137] IRP leadership aimed to reproduce the scale, efficiency, and interdisciplinarity of the malaria project and apply them to new problems. One intramural scientist's description of an early postwar effort to investigate heart disease illustrated this approach:

> There was to be a group in organic chemistry that would isolate and/or synthesize compounds that were effective against one or another aspect of heart disease. These would be passed up through the pharmacologists who would examine their distribution in the body and mechanism of action; another group would investigate their effects in experimental

131. Zoom Interview with Eric D. Green, Dir., Nat'l Hum. Genome Rsch. Inst. (Sep. 30, 2024).

132. *A Short History of the National Institutes of Health: Introduction*, NAT'L INSTS. HEALTH, https://history.nih.gov/display/history/A+Short+History+of+the+National+Institutes+of+Health [https://perma.cc/F3NH-4CPG]. Dr. Joseph J. Kinyoun was the only full-time researcher employed at the laboratory for its first ten years. *A Short History of the National Institutes of Health: The Move to Washington*, NAT'L INSTS. HEALTH, https://history.nih.gov/display/history/The+Move+to+Washington [https://perma.cc/E7RJ-YE69].

133. *A Short History of the National Institutes of Health: Introduction*, *supra* note 132.

134. *Id.*

135. NIH grants totaled $4 million in 1947 and had increased to $100 million by 1957. The entire NIH budget—intramural and extramural programs included—"expanded from $8 million in 1947 to more than $1 billion in 1966." *A Short History of the National Institutes of Health: WWII Research and the Grants Program*, NAT'L INSTS. HEALTH, https://history.nih.gov/display/history/WWII+Research+and+the+Grants+Program [https://perma.cc/R7YU-8ZPX].

136. Buhm Soon Park, *The Development of the Intramural Research Program at the National Institutes of Health After World War II*, 46 PERSPS. BIOLOGY & MED. 383, 399-400 (2003).

137. *Id.* at 393-94.

animals; and finally clinical groups would determine their usefulness in patients with cardiovascular disease.[138]

The IRP's history includes an extensive list of foundational advances in the biomedical sciences from the 1950s onward. These include the "cracking" of the genetic code, in which the mechanisms through which DNA codes for specific amino acids were identified, in 1961;[139] the identification of HIV as the cause of acquired immunodeficiency syndrome (AIDS) in 1984;[140] the discovery of the hepatitis C virus in 1989;[141] and, in recent years, the identification of partial genetic contributors to Parkinson's disease.[142] In addition to these major breakthroughs, IRP scientists have contributed to the ever-growing catalog of advances in disease-treatment protocols over the many decades of the program's existence. Six Nobel Prizes have been awarded to scientists for research conducted at the NIH,[143] and the list of laureates who passed through the IRP at some point in their career is far longer.

Over the past few decades, the NIH has conducted a number of external assessments of its IRP to better understand its comparative advantages as a research institution and to probe for potential areas of reform.[144] Each time,

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138. *Id.* at 394 (quoting Dr. Robert Berliner, the former scientific director of the National Heart Institute).

139. This work was performed by Dr. Marshall Nirenberg, who later shared the Nobel Prize. *Marshall Nirenberg Deciphering the Genetic Code: Introduction*, NAT'L INSTS. HEALTH, https://history.nih.gov/display/history/Nirenberg+Introduction [https://perma.cc/8W2V-CJMJ]; *Marshall Nirenberg: Deciphering the Genetic Code: The Code is Cracked!*, NAT'L INSTS. HEALTH, https://history.nih.gov/display/history/Nirenberg+History+Code+Cracked [https://perma.cc/Y8LU-YHSJ].

140. Dr. Robert Gallo made the critical advances in his lab at the NCI in 1984. *Gallo, Robert C. (1937-)*, NAT'L INSTS. HEALTH, https://history.nih.gov/illustrated-histories/nih-biographies-plus/robert-c-gallo-1937 [https://perma.cc/QX8X-65WP].

141. Dr. Harvey J. Alter performed this research while at the IRP and was awarded the Nobel Prize in 2020 for this work. Press Release, Nat'l Insts. of Health, NIH Intramural Researcher Dr. Harvey Alter Wins 2020 Nobel Prize in Physiology or Medicine (Oct. 5, 2020), https://www.nih.gov/news-events/news-releases/nih-intramural-researcher-dr-harvey-alter-wins-2020-nobel-prize-physiology-or-medicine [https://perma.cc/32NC-2YGA].

142. Dr. Ellen Sidransky and Andrew Singleton were awarded the 2024 Breakthrough Prize for this work. Intramural Rsch. Program, *Breakthrough Prize*, NAT'L INSTS. HEALTH (Sep. 14, 2023), https://irp.nih.gov/about-us/honors/breakthrough-prize [https://perma.cc/2ZHD-VTKE].

143. Intramural Rsch. Program, *Nobel Prize*, NAT'L INSTS. HEALTH (Dec. 13, 2024), https://irp.nih.gov/about-us/honors/nobel-prize [https://perma.cc/N9AF-Q9BS].

144. These introspective reform efforts began with the 1994 Report of the External Advisory Committee of the Director's Advisory Committee, also known as the "Marks-Cassell" report, named after the two cochairs of the external reviewers who conducted a program-wide

external reviewers, mostly biomedical scientists from academia, have identified critical features that distinguish the IRP from grant-funded biomedicine and have reaffirmed the continued place of the program in the national biomedical ecosystem.[145] While some changes have been made to the IRP research process, the basic institutional-design choices have remained virtually the same.

b. The Research Process

What most sets the IRP apart from the NIH's grant-based activities—and from the federal grant system as a whole—is the process by which research projects are selected and funded. As with most other grant-doling agencies, the NIH offers grants on a prospective basis: researchers submit proposals laying out research plans that they wish to pursue, reviewers at the NIH and peer institutions assess those proposals, and NIH staff ultimately determine whether to fund them.[146] Researchers funded through this system can carry out their projects only once a grant is secured; without grants, their research agendas are stalled or terminated. The active search for new grants—as well as the periodic renewal of existing ones—is thus a significant part of an extramural researcher's career. In his analysis of grant funding at the NIH, Price offers the following schematic:

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assessment of the IRP. The Marks-Cassell report recommended several tweaks to the investigator-review process, including strengthening the tenure and promotion process, improving recruitment efforts, and increasing diversity at the IRP. *See* External Advisory Comm. of the Dir.'s Advisory Comm., *Report of the External Advisory Committee of the Director's Advisory Committee*, NAT'L INSTS. OF HEALTH 2-3, 46-48 (Nov. 17, 1994), https://oir.nih.gov/system/files/media/file/2021-08/nih-irp_redbook.pdf [https://perma.cc/7ZWR-9XWE]. This was followed in 2004 with the NIH Director's Blue Ribbon Panel on the Future of Intramural Clinical Research, which recommended changing oversight protocols for clinical research and improving recruiting for patient-focused research careers. *See* Clinical Rsch. Blue Ribbon Panel, *NIH Director's Blue Ribbon Panel on the Future of Intramural Clinical Research*, NAT'L INSTS. OF HEALTH 7-9 (Jan. 2004), https://www.genome.gov/Pages/About/NACHGR/2004NACHGRAgenda/Tab%20H%20-%20BlueRibbonPanel.pdf [https://perma.cc/9BWG-9UNQ]. The most recent high-level review of the entire IRP was conducted in 2014 by an advisory committee that recommended various mechanisms for encouraging collaborative projects, among other suggestions. *See* Advisory Comm. to the Dir., *Long-Term Intramural Research Program (LT-IRP) Planning Working Group Report*, NAT'L INSTS. OF HEALTH 2 (Dec. 12, 2014), https://acd.od.nih.gov/documents/reports/ACD-IRP-WG-report.pdf [https://perma.cc/J798-6DL6].

145. *See* sources cited *supra* note 144.

146. For a detailed discussion of the NIH's prospective-funding system through grants, see Price, *supra* note 19, at 17-30.

FIGURE 1. SCHEMATIC OF SERIAL AND PARALLEL GRANTS FUNDED BY THE NIH'S EXTRAMURAL SYSTEM[147]

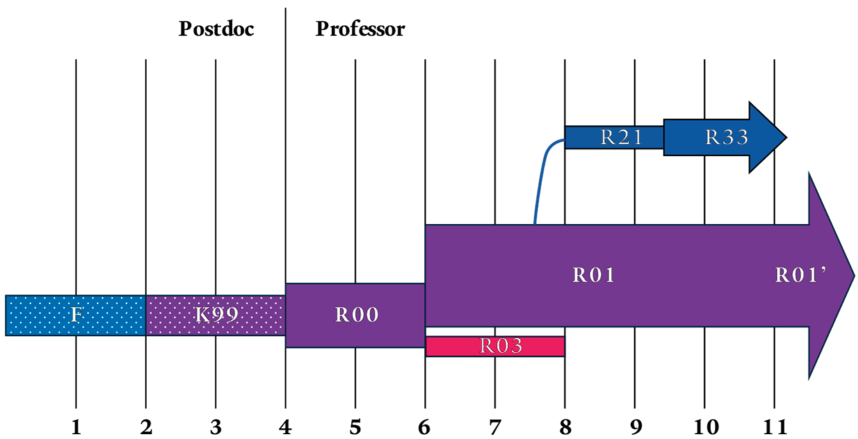


Figure 1 shows how a hypothetical researcher, whom Price calls "Jenn," might go about funding different lines of research over the course of the early part of her career.[148] After working as a postdoctoral researcher on "Project Blue," Jenn transitions to her primary research interest and secures grants for "Project Purple" in serial fashion, with a succession of larger grants.[149] Jenn also secures two parallel grants for "Project Red" and "Project Navy"—new lines of inquiry that emerge from earlier work and are funded on a smaller basis.[150] Each grant can only be used to fund work related to the line of research that Jenn sets out ex ante, and each requires an entirely new application process that Jenn must navigate.[151] In Price's hypothetical, this researcher undertakes this process seven times in just the first decade of her career after her Ph.D.

The NIH's intramural system is entirely different. IRP funding is, in contrast to extramural grants, largely retrospective: principal investigators are guaranteed a set amount of funding for a predetermined period of years (usually four),

147. *Id.* at 35 fig.1.

148. *Id.*

149. *Id.* at 36.

150. *Id.* at 37.

151. *Id.* at 35-37.

and their work is evaluated at the conclusion of each period.[152] Each researcher's collective output for the funding period is judged by a Board of Scientific Counselors (BSC), a body of about ten external peer reviewers with expertise in the researcher's field, joined by additional reviewers as needed.[153] Reviewers formulate their evaluations based on the significance, innovativeness, and quality of the investigator's work, as well as the lab environment and quality of mentorship for lab staff and postdoctoral candidates.[154] One of the criteria that distinguishes IRP review from the grant system asks whether the investigators are "taking advantage of the special resources and features of the NIH['s] distinctive intramural scientific environment."[155]

The BSC then issues a final recommendation to the Institute director indicating whether they believe the researcher in question should have their resources held constant, increased, or decreased.[156] The standards are high—one branch chief claimed BSCs "hold [IRP investigators] to R01 standards"[157]—and the results are consequential, determining investigators' level of funding over the subsequent four years. It generally takes two consecutive and clearly negative reviews for an institute to defund and shut down an investigator's lab.[158]

152. Intramural Rsch. Program, *IRP Review Process*, NAT'L INSTS. HEALTH (Jan. 13, 2022), https://irp.nih.gov/our-research/irp-review-process [https://perma.cc/2M78-JNNB].

153. JOHN A. KASTOR, THE NATIONAL INSTITUTES OF HEALTH: 1991-2008, at 10-11 (2010). The Board of Scientific Counselors review system was developed to meet the statutory requirements under 42 U.S.C. § 289a(b) (2024):

> The Director of NIH shall establish procedures for periodic technical and scientific peer review of research at the National Institutes of Health. Such procedures shall require that—
>
> > (1) the reviewing entity be provided a written description of the research to be reviewed, and
> > (2) the reviewing entity provide the advisory council of the national research institute involved with such description and the results of the review by the entity,
>
> and shall authorize such review to be conducted by groups appointed under sections 282(b)(6) and 284(c)(3) of this title.

154. Off. of the Dir., *Policies and Procedures to Guide Boards of Scientific Counselors in Reviewing Intramural Research at the NIH*, NAT'L INSTS. OF HEALTH 7-8 (July 6, 2017), https://oir.nih.gov/system/files/media/file/2021-08/policy-guide_bsc_reviewing_intramural_research.pdf [https://perma.cc/HN97-96AS].

155. *Id.* at 8.

156. Off. of Mgmt. Assessment, *NIH Policy Memo: 3005 - Review and Evaluation of Intramural Programs*, NAT'L INSTS. OF HEALTH 7-8 (Apr. 16, 2025), https://policymanual.nih.gov/chapter/export/3005/1?modelId=201fec77 [https://perma.cc/C7VP-P8KP].

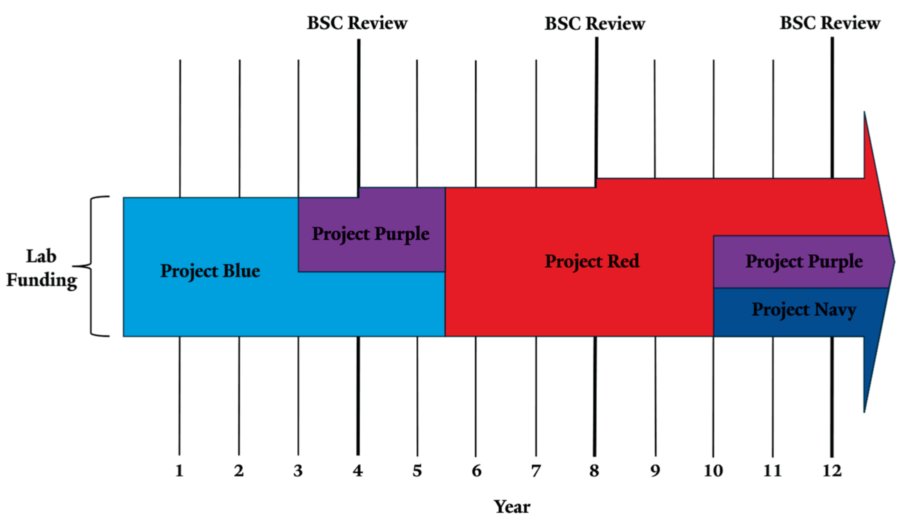
157. KASTOR, *supra* note 153, at 11.

158. *Id.* Kastor's survey of the NCI, the largest of the intramural programs at the NIH, found that forty of the three hundred laboratories were closed in the period from 2004 to 2008. *Id.*

Reviews are thus taken extremely seriously by investigators: former NIH Director Dr. Francis Collins describes BSC reviews as "a white-knuckle experience."[159] Investigators devote a substantial portion of the year in which they are reviewed to preparing their materials.[160]

Adapting Price's schematic for the extramural system, we can visualize here how a hypothetical intramural researcher—whom I will call "Jane"—might navigate the funding and research-selection system at the IRP:

FIGURE 2. SCHEMATIC OF THE NIH IRP FUNDING PROCESS



Jane begins her career at the IRP with a block of funding for four years to start her lab and hire personnel. For the first three years, her focus is entirely on Project Blue. But at the start of her fourth year, she begins Project Purple, a new line of research, and splits her resources between these two projects. After her first successful BSC review, Jane spends the following eighteen months splitting her resources between Projects Blue and Purple. Midway through year five, Jane becomes aware of a new and pressing research opportunity—perhaps a rapidly developing public-health crisis or a new subfield established by another researcher's breakthrough discovery. With two years left before her next review,

159. Zoom Interview with Francis Collins, *supra* note 10.

160. Zoom Interview with Daniel Kastner, Distinguished Investigator, Nat'l Insts. of Health (Mar. 13, 2024).

Jane decides to completely change course and devote the entirety of her resources to this new opportunity, Project Red.[161]

She spends the next two years working on Project Red, perhaps enough time to begin some major experiments, if not to publish one or two articles from her preliminary work. Her second BSC review notes the successes of Projects Blue and Purple and, despite a lack of major publications from Project Red, approves of her change in direction. Jane continues to focus on Project Red and makes several important contributions to this developing field. At the conclusion of her tenth year, Jane continues her work on Project Red but begins again to diversify her research, restarting her efforts on Project Purple to pick up where she left off four years earlier. Jane also begins Project Navy, an entirely new line of inquiry. Going into her third review at the conclusion of her twelfth year, Jane splits her research roughly evenly between these three projects. She passes her review, and Jane again begins another four-year period where she is free to pursue whatever research projects she wishes.

This hypothetical early-career path highlights some of the stark differences between the grant system and government research at the NIH. Unlike their colleagues in traditional academic posts, IRP scientists can develop a research agenda with near-total freedom over what research projects they pursue and when they pursue them—all provided that they are later able to defend their choices at the next retrospective review. IRP researchers can spend their careers focusing on a single line of research; they can also, as in Jane's example, pursue new interests and even shift course dramatically, without having to wait for the grant application cycle to play out. Moreover, they can do so without first having to develop a track record in a new field, one of the factors that makes it difficult for researchers to obtain large grants.[162] Four years of guaranteed funding provide a level of security that further enables this approach. While the NIH's extramural system invests in projects, the IRP invests "in the investigator."[163]

These funding and review structures create a research-selection process that gives the investigator "total flexibility"[164] and favors "high risk, high impact"

161. Though it is rare for an investigator to change focus areas completely, the point here is that the IRP funding system makes this possible. *Id.*

162. *See* Price, *supra* note 19, at 36. In his discussion of the K99/R00 grant, Price observes that "[g]etting this type of two-tiered award is contingent on Jenn's baseline qualifications, but also on how well she has done in her earlier work. It is therefore extremely challenging to get a K99/R00 grant without a record of peer-reviewed scientific publications." *Id.*

163. Zoom Interview with Daniel Kastner, *supra* note 160.

164. Zoom Interview with Eric D. Green, *supra* note 131.

projects more so than one might typically find in the NIH's extramural arm.[165] The IRP can also support projects of extraordinary length, since funding does not require constant renewal.[166] As Dr. Eric Green, former director of the National Human Genome Research Institute, tells it, "Almost any intramural investigator [will say about some of their work] . . . 'I would have never gotten funded for this if I had to write a grant.'"[167] Indeed, even some IRP Nobel laureates describe their prize-winning breakthroughs in this way.[168] Researchers inclined toward higher-risk and longer-term projects are thus particularly drawn to the IRP system.[169]

It is also a research process that can change course quickly. Since researchers avoid the months- or even years-long grant application process, they can turn "on a dime" to a new opportunity as soon as it presents itself.[170] Significant contributions in fields outside traditional disciplinary boundaries are common. For example, recent work by sociologist Natalie B. Aviles has cataloged a series of

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165. Zoom Interview with Anthony Fauci, *supra* note 9; *see also* KASTOR, *supra* note 153, at 4 ("An NIH appointment allows investigators to undertake promising projects with a higher-than-average risk of failing and to pursue the work for many years if necessary."). Kastor quotes Francis Collins, who would go on to become NIH director, as stating, "You have tremendous flexibility to chase after new ideas and to start the experiments at once instead of waiting for grants to be approved." KASTOR, *supra* note 153, at 5.

166. One example is the Baltimore Longitudinal Study on Aging, which has been run continuously since 1958 by an IRP research group that would become the National Institute on Aging's IRP program. Luigi Ferrucci, *NIA Intramural Research Program: Fueling the Next 50 Years of Aging Science Discovery*, NAT'L INST. AGING (July 17, 2024), https://www.nia.nih.gov/research/blog/2024/07/nia-intramural-research-program-fueling-next-50-years-aging-science-discovery [https://perma.cc/WPL2-CB42].

167. Zoom Interview with Eric D. Green, *supra* note 131.

168. Dr. Marshall Nirenberg (Nobel Prize in Physiology, 1968) noted in a 2009 interview that taking on his Nobel Prize-winning study of the mechanisms through which DNA is converted to amino acids was "dangerous, a dangerous thing to do" and "nobody would have given [him] a grant to do it because [he] had no experience in the field." Nirenberg concluded that the "NIH [is] the only place [he] could have done [this research]." NAT'L INSTS. OF HEALTH, *A Conversation with Dr. Marshall Nirenberg*, at 06:08-06:21 (YouTube, June 5, 2012), https://www.youtube.com/watch?v=fODwXbtysqQ [https://perma.cc/S5XJ-BHQC].

169. Dr. Robert Gallo, who codiscovered human immunodeficiency virus (HIV) as the cause of acquired immune deficiency syndrome (AIDS) while at IRP, identified himself as a "gambler" and described the NIH environment as a perfect fit. *See In Their Own Words: NIH Researchers Recall the Early Years of AIDS*, NAT'L INSTS. HEALTH 3-4 (1994), https://history.nih.gov/display/history/Dr.+Robert+Gallo?preview=/8881299/8881301/Gallo94-08.pdf [https://perma.cc/JZ7W-DGPK] ("There are many places where you cannot be a gambler because there is pressure for you to obtain year-to-year funding for your spending. But if you know you have money for five to ten years, or you are fairly certain of it, then you can ask longer-range questions in your scientific research.").

170. *See* Zoom Interview with Anthony Fauci, *supra* note 9; Zoom Interview with Eric D. Green, *supra* note 131.

fundamental advances in virus and vaccine research made by researchers at the National Cancer Institute.[171] Researchers are also freed up to consider factors beyond traditionally construed "scientific merit." They can, and often do, select projects based on "public health imperative[s]" and other public-interest-oriented considerations.[172] Specific examples of IRP-supported research bear out these generalizations.

Dr. Daniel Kastner, an IRP investigator who has focused much of his research on the genetic bases of inflammatory diseases and their potential treatments, chose in the mid-1980s to study familial Mediterranean fever (FMF), a debilitating autoinflammatory disorder named for its relative prevalence among populations in the Eastern Mediterranean region.[173] Kastner went "gene hunting"—working to identify the location in the human genome of the genetic basis for FMF—in order to improve testing and therapy for the condition. Hunting for the FMF gene was risky for Kastner on two grounds.[174] First, Kastner lacked experience in the newly developed methodology required to find the gene's location; and second, prior mapping of the genome was spotty at this time, and so finding the FMF gene years before the completion of the NIH's Human Genome Project[175] was a "needle-in-a-haystack" problem. Both would likely have been insurmountable barriers in securing funding through the nongovernmental system.[176] IRP funding posed no obstacle, however, and Kastner was free to take on the high-risk project immediately. The project's first breakthrough—finding

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171. Natalie B. Aviles, An Ungovernable Foe: Science and Policy Innovation in the U.S. National Cancer Institute 20-21 (2024).

172. Zoom Interview with Anthony Fauci, *supra* note 9.

173. Katie Hunt, *Mysterious Untreatable Fevers Once Devastated Whole Families. This Doctor Discovered What Caused Them*, CNN Health (Feb. 1, 2021, 7:02 AM EST), https://www.cnn.com/2021/02/01/health/daniel-kastner-rare-diseases-autoinflammatory-scn [https://perma.cc/DL74-FHWH]. Dr. Kastner began his work on Mediterranean fever at the National Institute of Arthritis and Musculoskeletal and Skin Diseases before switching to the National Human Genome Research Institute in 2010.

174. Zoom Interview with Daniel Kastner, *supra* note 160.

175. The Human Genome Project, launched in 1990 and completed in 2003, was a multibillion-dollar effort to generate a complete genome sequence of a human being that would serve as a reference for further genetic research. Importantly, the project was entirely extramural, with funding doled out by the NIH to several research contractors, each of which would be responsible for a different segment of the genome. *See Fact Sheet: Human Genome Project*, NIH Nat'l Hum. Genome Rsch. Inst. (June 13, 2024), https://www.genome.gov/about-genomics/educational-resources/fact-sheets/human-genome-project [https://perma.cc/R7DR-QPH7].

176. Zoom Interview with Daniel Kastner, *supra* note 160.

the location of the FMF gene on chromosome 16 – came within two years, in time for Kastner's first successful BSC review.[177]

The freedom and flexibility of the IRP research process have also enabled researchers to respond to emerging health crises without the delays that often accompany grant procurement. As discussed in the Introduction, the VRC at the NIAID was able to mobilize its resources immediately in response to the emerging COVID-19 epidemic.[178]

Dr. Anthony Fauci, who led NIAID for nearly forty years, took advantage of this flexibility years prior to his leadership during the COVID-19 pandemic. Fauci spent the early part of his career as an IRP investigator focused on the regulation of the human immune response and autoinflammatory diseases.[179] In 1981, Fauci encountered a mystifying report detailing what appeared to be a rare form of pneumonia in five otherwise-healthy gay men in Los Angeles.[180] Similar reports in the coming weeks confirmed that this was an entirely new infectious agent with the potential to become an epidemic. Fauci decided to overhaul his entire research program toward the study of what would soon be named AIDS.[181] This was a risky move at the time, as it was not yet clear how widespread the disease would become.[182] But Fauci's pivot was prescient and vital, establishing one of the first AIDS research programs in the world and one that would contribute to a host of advances in scientific understanding and clinical treatment of the disease. Without the freedom and flexibility of the IRP research process, Fauci would not have been able to begin his AIDS work at such an early phase of the epidemic.[183]

Another distinctive feature of work at the IRP is the researchers' access to the NIH Clinical Center, the world's largest hospital devoted entirely to clinical research.[184] All care provided to patients at the Clinical Center is fully funded by the NIH; neither insurance companies nor patients themselves ever have to pay.

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177. *Id.*

178. For discussion of the VRC's work on the mRNA-based COVID-19 vaccines, see *supra* Introduction.

179. FAUCI, *supra* note 1, at 28-29.

180. *Id.* at 33-34.

181. *Id.* at 39.

182. *Id.*

183. *See* Zoom Interview with Anthony Fauci, *supra* note 9.

184. The Clinical Center is comprised of two building complexes: the older Magnuson Center, which houses over five thousand rooms and fifteen outpatient clinics, and the newer Hatfield Center, which has two hundred inpatient beds and eighty-two day-hospital stations. *See* Intramural Rsch. Program, *Clinical Center Facilities*, NAT'L INSTS. HEALTH (Jan. 14, 2025), https://irp.nih.gov/nih-clinical-center/clinical-center-facilities [https://perma.cc/6XVH-WGSC].

IRP researchers can thus conduct clinical research for new therapies quickly, since "[m]any research laboratories are literally just around the corner from the rooms of clinical trial participants,"[185] and researchers can work with these patients without needing to raise any money. The IRP claims that the approach facilitated by the Clinical Center has supported "research concepts so nascent that no scientific literature existed that could support a traditional grant application."[186]

The research process at the IRP is also characterized by a higher degree of collaboration than one might find in other settings. By avoiding some of the entanglements that can arise when trying to use grant funding collaboratively, IRP researchers can more easily form teams to tackle problems of cross-disciplinary interest.[187] Physical proximity can also encourage collaboration: most IRP labs are based at the Bethesda headquarters, and intellectual cross-pollination often requires only a walk downstairs.[188] IRP leadership has published a "Collaboration and Team Science Field Guide" for its investigators and has implemented policies to explicitly encourage the pursuit of multidisciplinary projects.[189] Tenure requirements now include "recognition of significant participation in research teams," and a series of award programs exist for trans-IRP collaborations.[190] These efforts continue to bear fruit: a recent internal assessment found that seventy-one percent of IRP researchers collaborated with other labs over a three-year period.[191]

185. Intramural Rsch. Program, *Advancing Translational Science*, NAT'L INSTS. HEALTH (Jan. 10, 2022), https://irp.nih.gov/nih-clinical-center/advancing-translational-science [https://perma.cc/59U4-L2GT].

186. Intramural Rsch. Program, *Clinical Trials*, NAT'L INSTS. HEALTH (Jan. 10, 2022), https://irp.nih.gov/nih-clinical-center/clinical-trials [https://perma.cc/6PF2-UR9N].

187. Zoom Interview with Eric D. Green, *supra* note 131.

188. Zoom Interview with Anthony Fauci, *supra* note 9.

189. L. Michelle Bennett & Christophe Marchand, *Developing Science Teams Form, Storm, Norm, and Perform*, NAT'L INSTS. HEALTH (July 5, 2023), https://irp.nih.gov/blog/post/2019/08/developing-science-teams-form-storm-norm-and-perform [https://perma.cc/B666-32DT].

190. Michael Gottesman, *My Time as Deputy Director for Intramural Research: The Recent Years*, NIH CATALYST, Mar.-Apr. 2022, at 2, 2. The IRP offers additional funding for "team[s] of 3 to 5 independent investigators" through its DDIR Innovation Awards program. Off. of Intramural Rsch., *DDIR Innovation Awards*, NAT'L INSTS. HEALTH (Aug. 4, 2021), https://oir.nih.gov/about/ddir-innovation-awards [https://perma.cc/865C-HGNL].

191. Gottesman, *supra* note 190, at 2.

c. *Incentives*

The IRP grants tenure to investigators who demonstrate a productive record, and this, much like in traditional academia, serves as a primary motivation during the initial phase of IRP researchers' careers. Pretenure IRP investigators are very much in a "publish or perish" environment. After tenure, there remains the motivation of the next BSC review, which, as noted above, determines the level of resources that investigators are allocated in the years to come.

The IRP does not offer salaries competitive with industry or much of biomedical academia.[192] Nor does it allow its researchers to take full advantage of other income sources to which academic researchers might turn. IRP investigators are prohibited from receiving paid consulting work or even speaker fees,[193] and perhaps most importantly, there is a cap on the annual income investigators can earn from royalties based on patents generated from IRP work, with the rest going directly to the IRP itself.[194] The patented breakthroughs that led to the development of the Moderna mRNA vaccine,[195] for example, have resulted in an uptick of tens of millions of dollars in royalty revenue for the NIH, but the named inventors have been limited by this cap.[196] Technology transfer is thus an underlying facet of investigators' motivations at the IRP, but it may not play as

192. Zoom Interview with Eric D. Green, *supra* note 131. IRP salaries are regulated directly by Congress and are set under Title 42. 42 U.S.C. § 209 (2024).

193. Zoom Interview with Eric D. Green, *supra* note 131.

194. IRP investigators are limited to $150,000 per year in royalty income. *Information for NIH Inventors*, NAT'L INSTS. HEALTH, https://www.techtransfer.nih.gov/royalties/information-nih-inventors [https://perma.cc/Q52D-6XB6].

195. *See, e.g.*, Anti-Coronavirus Antibodies and Methods of Use, U.S. Patent No. 0150438 (filed Mar. 31, 2023).

196. The NIH took in $730 million in patent-royalty revenues over a two-year period from 2021-2023, a substantial increase from the prepandemic period, and only $25.5 million went to individual investigators. *See* Jon Cohen, *Accusers' Bad Math: NIH Researchers Didn't Pocket $710 Million in Royalties During Pandemic*, SCIENCE (June 7, 2024, 5:40 PM ET), https://www.science.org/content/article/bad-math-nih-researchers-didn-t-pocket-710-million-royalties-during-pandemic [https://perma.cc/3B9D-Y7RK]. This issue has recently become politicized, as some on the political right have wrongfully accused NIH researchers of personally earning many millions of dollars per year based on COVID-19 vaccine-related patents. *See Heated Exchange Between Sen. Rand Paul and Dr. Anthony Fauci*, CSPAN (June 16, 2022), https://www.c-span.org/video/?c5020101/heated-exchange-sen-rand-paul-dr-anthony-fauci [https://perma.cc/K227-TD4U]. The irony of these attacks is that IRP-based research may be only patented and commercialized in the first place due to the series of congressional acts of the 1980s endorsing technology transfer from federal research agencies (e.g., Stevenson-Wydler, Bayh-Dole, and their associated policies). *See* Cohen, *supra*.

large a role as in academia.[197] A study conducted in the early 1990s by the U.S. General Accounting Office, for example, found that the monetary incentives provided by royalty sharing in GOGO labs did not meaningfully change the behavior of researchers.[198] Other work has found that IRP researchers in particular may seek patents not primarily as a source of supplemental income but as a means "to help move one's research beyond the laboratory."[199]

The IRP must therefore rely on other incentives to recruit, retain, and motivate its investigators. The significant freedom of the IRP's funding structure serves as one such incentive. Without the teaching obligations of a university post or the near-constant need to secure the next grant, researchers can focus almost entirely on the science, and this can compensate for some of the monetary factors noted above.[200] Some IRP researchers also enjoy the sense of national mission and public service—"the prestige of being able to say 'I work at the NIH'"[201]—that comes with an NIH investigator role. The IRP's status can also give some investigators "a bully pulpit to advance [their] field in a public way."[202] Even researchers not in leadership positions can have some influence on national biomedical policy: investigators can relay information to their institute director, who can inform the NIH Director, who has a direct line to the White House.[203] Academic and industry scientists find themselves further from the halls of power.

197. Citing a Congressional Research Service study from 2000, the Information Technology and Innovation Foundation asserts that "allowing U.S. institutions to earn royalties through the licensing of their research provided a powerful incentive for universities and other institutions to pursue commercialization opportunities." Stephen Ezell, Meghan Ostertag & Leah Kann, *The Bayh-Dole Act's Role in Stimulating University-Led Regional Economic Growth*, INFO. TECH. & INNOVATION FOUND. 6 (June 2025), https://www2.itif.org/2025-bayh-dole-regional-growth.pdf [https://perma.cc/VA93-BLUN]. *But see* Lisa Larrimore Ouellette & Andrew Tutt, *How Do Patent Incentives Affect University Researchers?*, 61 INT'L REV. L. & ECON. art. no. 105883, at 5-16 (2020) (finding that the prospect of patent royalties does not meaningfully motivate university researchers but leaving open the possibility of other patent-related incentives, including faculty-run spin-offs).

198. *Technology Transfer: Barriers Limit Royalty Sharing's Effectiveness*, U.S. GEN. ACCT. OFF. 3-4 (Dec. 1992), https://www.gao.gov/assets/rced-93-6.pdf [https://perma.cc/SA6E-MXWT].

199. David H. Guston, *Stabilizing the Boundary Between US Politics and Science: The Role of the Office of Technology Transfer as a Boundary Organization*, 29 SOC. STUD. SCI. 87, 103 (1999).

200. Zoom Interview with Daniel Kastner, *supra* note 160, at 4-6.

201. KASTOR, *supra* note 153, at 4.

202. *Id.* at 5 (quoting Dr. Anthony Fauci's discussion of his work on HIV/AIDS).

203. Zoom Interview with Eric D. Green, *supra* note 131.

2. *Lawrence Livermore National Laboratory*

a. *Overview*

Lawrence Livermore National Laboratory is one of the largest of the Department of Energy's (DOE) seventeen national laboratories.[204] With physical facilities occupying a full square mile in Livermore, California, LLNL employs over nine thousand people, the majority of whom hold research-based or technical positions.[205] Along with Sandia and Los Alamos National Laboratories, LLNL is a "National Nuclear Security Administration Laboratory" that focuses broadly on national-security-related science and technology, though this umbrella has come to include fields not traditionally associated with national security. In keeping with the institutional structure of the other national labs, LLNL uses a GOCO model funded by DOE and operated by an LLC.[206] It is thus generally representative of the national-lab model in government research.

LLNL's storied history includes many of the breakthroughs that shaped international technological rivalries in the twentieth century. Founded in 1952 under the auspices of the Atomic Energy Commission (AEC) as Cold War tensions were rising, the lab initially focused on the development of a thermonuclear bomb, the sequel to the Manhattan Project that had concluded just a few years earlier.[207] While thermonuclear weaponry began as its exclusive focus, LLNL's

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204. According to the Department of Energy's figures on the annual budgets for the national labs, only Los Alamos National Laboratory (around $4.5 billion in FY 2023) and Sandia National Laboratory (around $3 billion in FY 2023) received more funding than LLNL (around $2.3 billion in FY 2023). *DOE FY 2024 Laboratory Table*, U.S. DEP'T ENERGY 1-3 (2024), https://www.energy.gov/sites/default/files/2023-06/doe-fy2024-budget-lab-table-v2.pdf [https://perma.cc/J427-ZRR5].

205. *By the Numbers: Tracking Our Effort: FY 24 Funding by Source*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://www.llnl.gov/about/by-the-numbers [https://perma.cc/8APK-93VM]; *About LLNL: Ideals in Action: Science and Technology on a Mission*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://www.llnl.gov/about [https://perma.cc/7F57-RJYA].

206. *Management and Sponsors: Providing Critical Support: Government Owned, Contractor Operated*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://www.llnl.gov/purpose/management-sponsors [https://perma.cc/G74P-YCQH]. The current contractor is Lawrence Livermore National LLC, which assumed operation of LLNL in 2007. *Id.* This LLC was created specifically to manage and operate the lab. *Id.* Historian Peter J. Westwick attributes the GOCO structure of Livermore and all other national labs as the result of path dependency coming out of the contractor-dominated research system pioneered by Vannevar Bush during the war. *See* PETER J. WESTWICK, THE NATIONAL LABS: SCIENCE IN AN AMERICAN SYSTEM, 1947-1974, at 43-47 (2003).

207. Though the Manhattan Project is most closely associated with the military-run laboratory in Los Alamos, New Mexico, and the nearby "Trinity" test of the first atomic bomb that founders had broader ambitions for the lab. AEC Commissioner Gordon Dean recognized early on that "the laboratory's freedom to seek . . . new ideas would make a clear program definition impossible."[208] Research leadership naturally gravitated to the projects that lab staff found most compelling. Inaugural LLNL Director Herbert York outlined this "basic policy" as "mak[ing] technology as interesting as pure science by pressing at the extremes, whether there was any interest for them in Washington or not."[209] Lab-initiated project selection would continue to be a core feature of LLNL's overall R&D approach.

Having found success with the hydrogen bomb, LLNL scaled up and began to expand its focus by the late 1950s, developing capabilities in computing and engineering beyond what thermonuclear research demanded.[210] The lab pioneered basic features of the modern computing era, including early forms of computer networking and memory storage.[211] With the thawing of Cold War tensions in the 1970s, LLNL's research turned increasingly to technologies with civilian applications—most significantly, the development of a world-leading research program in lasers and their applications.[212] The lab also developed a focus on nuclear energy, which increased significantly with the end of the Cold War in the late 1980s. As LLNL expanded its scientific reach and amassed more areas of expertise over the decades, the lab itself transformed from a "quasi-cottage

concluded the project, the entire enterprise was actually split between various locations over several years. Like the individual lab at Los Alamos, several of these locations were maintained as national labs and scaled up after the war, including Oak Ridge National Laboratory in Tennessee and the Radiation Laboratory at Berkeley, which became Lawrence Berkeley National Laboratory. For a history of the Manhattan Project and the development of the atomic bomb, see generally RHODES, *supra* note 99. For a history of the national-laboratory system in the immediate postwar period, see generally WESTWICK, *supra* note 206.

208. C. BRUCE TARTER, THE AMERICAN LAB: AN INSIDER'S HISTORY OF THE LAWRENCE LIVERMORE NATIONAL LABORATORY 26-27 (2018) (quoting AEC Commissioner Gordon Dean).

209. *Id.* at 43.

210. C. Bruce Tarter notes that LLNL's budget increased by more than a factor of ten in its first decade of operation. *See id.* at 85. Computing power was needed to perform the complex calculations for the optimization of nuclear-weapon design. *See id.* For these calculations, LLNL purchased the world's first "supercomputer," the IBM 701, as well as several others from IBM. *See id.* LLNL's role as an early procurer of the highest-end computers was likely critical to the early development of the computer industry in the postwar era. *Our History: Making History and a Difference*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://www.llnl.gov/purpose/history/1950s#event-bigger-faster-and-larger-computers [https://perma.cc/RRQ5-Z2XX]; *see also* WESTWICK, *supra* note 206, at 240 (describing how the scientists at LLNL pushed for technological advancements to keep pace with competing labs).

211. *See* William Lokke, *Early Computing and Its Impact on Lawrence Livermore National Laboratory*, LAWRENCE LIVERMORE NAT'L LAB'Y 16 (Mar. 21, 2007), https://www.osti.gov/servlets/purl/902225 [https://perma.cc/4D8P-RXF4].

212. TARTER, *supra* note 208, at 167, 170-72.

industry" to "one of the largest and most diverse research and development organizations in the country."[213]

Today, the lab maintains a wide-ranging portfolio of scientific projects, many of which are linked only indirectly to national security and nuclear threats. LLNL continues to possess and refine several of the world's most powerful supercomputers, which are now being used to push the frontiers of artificial intelligence (AI).[214] In late 2022, LLNL made international headlines when it reported the first successful controlled-fusion experiment to reach "ignition," generating more energy from nuclear fusion than the energy used to initiate the reaction.[215] Ignition was obtained at the lab's National Ignition Facility, the world's highest-energy laser facility, using an LLNL-developed technique called inertial-confinement fusion. The achievement was the culmination of more than sixty years of R&D at LLNL on nuclear physics, lasers, optics, materials science, and computer modeling.[216] Beyond the event's historic significance, the breakthrough reaffirmed LLNL's position at the global technological frontier. These focus areas—high-energy-density science and computing, along with materials and manufacturing—remain the lab's leading strengths.[217]

b. *The Research Process*

LLNL's current research portfolio falls under four "missions areas": (1) nuclear deterrence, which focuses on maintaining the U.S. nuclear stockpile; (2) threat preparedness and response, which anticipates and develops countermeasures for nuclear and biological attacks; (3) climate and energy security, which models climate change and develops carbon-free energy sources; and (4) multidomain deterrence, a catchall category that aims to maintain U.S. technological supremacy through a number of emerging technologies.[218] These broad focus

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213. *Id.* at 203.

214. *See infra* Section III.B.1 (discussing state capacity).

215. Media coverage included a segment on *60 Minutes* and even a skit on *Saturday Night Live*. *See* 60 MINUTES, *Nuclear Fusion: Inside the Breakthrough that Could Change Our World* (YouTube, Jan. 15, 2023), https://www.youtube.com/watch?v=2kh6Ik4-yag [https://perma.cc/KHC4-SCC2]; SATURDAY NIGHT LIVE, *Fusion Scientist* (YouTube, Dec. 20, 2022), https://www.youtube.com/watch?v=BpcxRQobzaw [https://perma.cc/98EB-XHN8].

216. *Program Overview: Laboratory Directed Research and Development, Fiscal Year 2023 Annual Report*, LAWRENCE LIVERMORE NAT'L LAB'Y 35-37 (2024), https://ldrd-annual.llnl.gov/sites/ldrd_annual/files/2024-06/ldrd-overview-fy23.pdf [https://perma.cc/YUG2-H8BB].

217. Zoom Interview with Patricia Falcone, Deputy Dir. for Sci. & Tech., Lawrence Livermore Nat'l Lab'y (Sep. 18, 2024).

218. *See Our Mission: Strengthening National Security*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://www.llnl.gov/purpose/missions [https://perma.cc/T7P4-6ZG2].

areas are determined by DOE and passed on to the lab to provide overall guidance for its many research activities. All R&D projects pursued at LLNL must fall under one of these umbrellas.

The selection process for new projects is split between external planning from LLNL's funding sources—chiefly DOE's National Nuclear Security Administration (NNSA)—and internal initiatives that give LLNL researchers more control and input over what they want to pursue.[219] In the former case, NNSA identifies long-term projects that speak directly to the lab's core mission in the broader context of the national-security enterprise. For example, research projects geared toward the maintenance of the federal government's nuclear stockpile, which the lab identifies as its "foremost responsibility,"[220] are mandated directly by NNSA, though lab scientists still retain some control over project specifics. For several years, LLNL has been a leading research unit in NNSA's "W80-4 Life Extension Program," a fourteen-year project to recertify a set of thermonuclear warheads.[221] The National Ignition Campaign, a multiyear funding commitment by NNSA that directly supported fusion-related work at the ignition facility, is another example of externally directed project selection.[222]

While research supported in this way is relatively constrained, with project goals and milestones largely dictated by national-security authorities, the other system of research selection at LLNL is more open. This latter channel is known as Laboratory Directed Research and Development (LDRD) and acts as an internal grant program supporting "high-risk" projects in "forefront areas of science and technology."[223] The LDRD program was created in the 1980s during a moment of institutional reflection and reform at the lab. Taking direct inspiration from successful models of large-scale corporate R&D,[224] LLNL leadership conceived of LDRD as a means for researchers to pursue "topics of interest outside the weapons program" and diversify the lab's portfolio.[225]

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219. Zoom Interview with Xiaoxing Xia, Staff Scientist, Lawrence Livermore Nat'l Lab'y (Oct. 4, 2024).

220. *See FY 2023 Annual Report*, LAWRENCE LIVERMORE NAT'L LAB'Y 4-5 (2024), https://annual.llnl.gov/sites/annual/files/2024-02/fy2023annual.pdf [https://perma.cc/T599-EWPF].

221. *See W80-4 Life Extension Program*, NAT'L NUCLEAR SEC. ADMIN. 2, https://www.osti.gov/servlets/purl/1357921 [https://perma.cc/E6NC-CMCU].

222. *See* Lynda Seaver, *NNSA Announces Important Milestone in the National Ignition Campaign*, LAWRENCE LIVERMORE NAT'L LAB'Y (Nov. 6, 2009), https://www.llnl.gov/article/34476/nnsa-announces-important-milestone-national-ignition-campaign [https://perma.cc/DS8T-9KE4].

223. *Program Overview*, *supra* note 216, at 1.

224. *See* discussion *infra* Section III.A.1 (addressing the parallels between large-scale corporate research and intramural research).

225. TARTER, *supra* note 208, at 210-11.

This program eventually became the major vehicle through which discretionary research takes place at LLNL and is now recognized as the final step of the "peaceful revolution" that transformed the lab "from a weapons institution into one in which a variety of technical enterprises could coexist and flourish."[226] In fiscal year 2023, the LDRD program supported 260 projects spanning a wide range of topics, all linked in some way to the lab's programmatic areas.[227] LLNL advertises the LDRD program as the lab's major source of innovative dynamism: LDRD projects account for the majority of new patents obtained by the lab each year, nearly half of its scientific-publication output, and nearly half of LLNL's "R&D 100" awards.[228]

The process for selecting an R&D project under the LDRD program resembles that of the grant system described by Price, but with some important distinctions. Each year, the LLNL director releases a call for proposals to all scientific and technical staff, inviting applications for new projects. Specific subject matter is rarely identified in these calls; rather, discretion is left to the proposing researchers to come up with creative projects that advance the lab's mission.[229] This discretion allows lab scientists to "feel they have an ability to create new ideas and new pathways and new approaches" within the lab's overarching mission-driven approach.[230]

Before researchers even apply for funding, they often informally "socialize" their ideas with would-be reviewers and potential collaborators to obtain iterative feedback.[231] Once submitted, applications are assessed internally for both "intellectual merit" and "strategic alignment" with LLNL's overall aims.[232] These review processes are required by law under DOE regulations.[233] Intellectual

226. *Id.* at 211.

227. *Program Overview*, *supra* note 216, at ii.

228. *Id.* at 7, 10, 19.

229. *See Laboratory Directed Research and Development Policies and Procedures Manual*, LAWRENCE LIVERMORE NAT'L LAB'Y 2 (Oct. 3, 2016), https://www.governmentattic.org/23docs/LLNLldrdppmAndNNSAdpbps_2016.pdf [https://perma.cc/M2BC-6KUM]. This document was obtained by FOIA request 17-00042-M and released for public distribution by the National Nuclear Security Administration. *Id.* at 2.

230. Zoom Interview with Doug Rotman, Lab'y Directed Rsch. & Dev. Program Dir., Lawrence Livermore Nat'l Lab'y (Sep. 18, 2024).

231. Zoom Interview with Xiaoxing Xia, *supra* note 219.

232. *Laboratory Directed Research and Development Policies and Procedures Manual*, *supra* note 229, at 4. By contrast, the category of "laboratory-wide" research does not require strategic alignment. *Id.* at 3.

233. U.S. DEP'T OF ENERGY, ORD. 413.2B, LABORATORY DIRECTED RESEARCH AND DEVELOPMENT: CONTRACTOR REQUIREMENTS DOCUMENT 2 (2006) (stating that Laboratory Directed Research and Development (LDRD) programs must "[e]stablish criteria that merit is determined by a process of peer review "using criteria that are consistent with those used across the scientific community."[234] Peer-review panels consist primarily of subject-matter experts from within the lab, but occasionally include external reviewers from universities or other government labs.[235]

Strategic alignment, by contrast, is reviewed by "designated leaders in the strategic focus areas" to which the project would contribute.[236] DOE and NNSA must then sign off on all proposed projects before funding is secured.[237] The overall review process is thus a synthesis of the typical extramural grant model and a mechanism to further LLNL-specific aims.[238] Projects underway are assessed annually by LLNL staff "to ensure technical success and continued alignment with mission objectives,"[239] and project leaders must submit a final report at the conclusion of their project at publication-level detail.[240]

One of the defining features of research at LLNL is the lab's unique facilities, which permit research at an extremely large scale. The National Ignition Facility is a prime example: a stadium-sized physical complex housing 192 of the world's most powerful lasers—amounting collectively to the world's largest laser—that converge on a single peppercorn-sized target.[241] Construction of the facility took twelve years and cost $3.5 billion.[242] The facility is used primarily by LLNL researchers but is also made available for cooperative research with university and industry R&D groups. It thus serves as a fundamental piece of infrastructure for inertial-confinement fusion research across the country.

Other resources at LLNL are similarly titanic. The lab recently completed installation of "El Capitan," a new supercomputer occupying an entire lab floor that performs calculations at the exascale, or one quintillion precise operations

emphasize innovative scientific and technological excellence for selection of projects using internal peer and/or technical management review").

234. *Laboratory Directed Research and Development Policies and Procedures Manual*, *supra* note 229, at 4.

235. *Id.* at 5.

236. *Id.* at 4.

237. *Id.*

238. There is a category of LDRD projects called "Laboratory-Wide" projects that do not need to address the lab's strategic goals. *Id.* at 3. These are typically smaller projects designed to address "innovative research concepts and ideas" with more minimal oversight. *Id.* at 5.

239. *Program Overview*, *supra* note 216, at 2.

240. *Laboratory Directed Research and Development Policies and Procedures Manual*, *supra* note 229, at 6.

241. *How NIF Works*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://lasers.llnl.gov/about/how-nif-works [https://perma.cc/88T9-64BK].

242. *NIF FAQs*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://lasers.llnl.gov/about/faqs#nif_cost [https://perma.cc/LJ7E-3959].

per second, making it the world's fastest operating computer.[243] El Capitan is being used to perform nuclear-physics calculations linked to LLNL's stockpile-preservation work, but the lab is also exploring other applications, including machine learning and AI.[244] The scale of other facilities is dictated by safety concerns. LLNL's "Site 300" is a 7,000-acre explosive-materials testing site located fifteen miles east of the lab's main campus.[245] Site 300's size and location allow for the safe operation of testing facilities for weapons and hazardous materials.

The large research equipment at LLNL—and the enormous staff required to operate it—is characteristic of the national-lab model generally.[246] Historian Peter Westwick, writing on the early days of the national-lab system, explains that "the scale and expense of research reactors and accelerators put them beyond the reach of individual universities," an advantage noted by the fledgling AEC.[247] Size was also a critical feature of the "crash program" approach to technology development epitomized by the Manhattan Project and its offspring.[248]

From its founding onward, the research process at LLNL has also used interdisciplinarity as a key strategy for maintaining its scientific edge. The size and variety of expertise in LLNL's workforce allowed the lab to form teams of scientists and engineers from a range of fields who each bring something different to their projects.[249] The lab encourages interdisciplinary work through its organizational structure. LLNL is split between several "organizations" linked to areas

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243. *El Capitan: NNSA's First Exascale Machine*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://asc.llnl.gov/exascale/el-capitan [https://perma.cc/S9U6-BFYP].

244. *Id.*

245. *Site 300 Experimental Test Site*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://sd.llnl.gov/facilities/hydrodynamic-explosives-testing/site-300-experimental-test-site [https://perma.cc/YDL9-S43B].

246. See, for example, the miles-long particle accelerator at the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois. *DUNE at LBNF*, FERMILAB, https://lbnf-dune.fnal.gov [https://perma.cc/FEM4-64XH].

247. WESTWICK, *supra* note 206, at 8.

248. *Id.*

249. Former LLNL Director Bruce Tarter describes this approach as

> a system in which teams could be quickly assembled for specific needs (such as a nuclear test) or for projects of years-long duration and then dissolved when the activity had run its course. Thus, an engineer could look forward to many different assignments over the course of a career . . . . The lead scientist could also blend different personalities and skills to create the group that he thought was best suited to a particular project.

TARTER, *supra* note 208, at 32.

of expertise.[250] Following a "matrix model," these organizations provide homes for researchers while allowing them to work across the lab for other organizations with different focus areas.[251]

For many LLNL projects, including some of the larger, federal-agency-planned initiatives, multidisciplinary teams are formed out of necessity. The convergent nature of these technological challenges requires teams with a wide variety of expertise that can bring "whatever is needed" to bear on the problem.[252] One result of this strategy is a technical workforce that includes both the domain experts one might find in a university setting, but also a technical staff that serves as generalist problem solvers. This latter group includes people "who just like to learn new things" and are capable of translating skills and knowledge across domains.[253]

c. Incentives

LLNL researchers are driven by many of the same incentives that undergird R&D in universities and industry. Lab staff are often motivated by "classic metrics" of academic success, including "publications, journal covers, invited papers, honorary awards . . . recognition in the National Academy, and the like."[254] Researchers can earn royalties on licensed patents for inventions developed at the lab, and LLNL maintains a solid record of spinning off start-ups from successful projects.[255] Still, several features distinguish the incentives at LLNL from those of a corporate or traditional academic setting. There is no tenure at LLNL—nor at any of the national labs—and early-career scientific staff need not adopt the "publish or perish" mentality as a result.[256] And while a successful LDRD-funded project may help yield more supported projects down the road, lab

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250. These include Computing, Engineering, Global Security, the National Ignition Facility and Photon Science, Operations and Business, Physical and Life Sciences, and Strategic Deterrence. *Our Organizations: Many Ideas, One Lab*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://www.llnl.gov/about/organizations [https://perma.cc/3GHU-PZB6].

251. *LLNL Hybrid Workplace Guide*, LAWRENCE LIVERMORE NAT'L LAB'Y 15 (2021), https://www.llnl.gov/sites/www/files/2022-04/hybrid-workplace-guide.pdf [https://perma.cc/SQ6J-GPLR].

252. Zoom Interview with Doug Rotman, *supra* note 230.

253. Zoom Interview with Patricia Falcone, *supra* note 217.

254. *Id.*

255. *See* BIG IDEAS LAB: *Tech Transfer* (Apple Podcasts, Mar. 18, 2025), https://podcasts.apple.com/us/podcast/tech-transfer/id1766302914?i=1000699645096 [https://perma.cc/434Q-3D9G].

256. *Id.*

researchers are not reliant on LLNL's internal grant program—there is always a fully funded project to work on regardless.

Technology transfer is alive and well at LLNL, as it is at many of the national labs.[257] Technology transfer was made an integral part of LLNL's responsibilities following the passage of the National Competitiveness Technology Transfer Act of 1989; this statute extended the objectives of the earlier Stevenson-Wydler Act, which sought to promote technology transfer from federal agencies.[258] The lab now tries to spin off its technology by licensing its patents to the private sector and by establishing Cooperative Research and Development Agreements (CRADAs) with private partners aiming to develop commercial products with lab technology. In the early 2000s, Adam Jaffe and Josh Lerner found that LLNL maintained an active patent-licensing and CRADA portfolio on par with an active research university and that such activity had increased following the reforms of the 1980s.[259] A substantial body of work assesses whether Bayh-Dole has skewed R&D at universities in an overly commercial direction.[260] It is beyond the scope of this case study to determine whether any similar impact on the direction of research at LLNL or the national labs has occurred due to Stevenson-Wydler and its extensions.

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257. *See generally* David C. Mowery & Arvids A. Ziedonis, *The Commercialisation of National Laboratory Technology Through the Formation of "Spin-off" Firms: Evidence from Lawrence Livermore National Laboratory*, 3 INT'L J. MFG. TECH. MGMT. 106 (2001) (finding that spin-off formation rates from LLNL are consistent with the rates at other larger national labs).

258. Rebecca S. Eisenberg, *Ownership, Commercial Development, Transfer and Use of Publicly Funded Research Results: The United States Legal Regime*, *in* U.N. CONFERENCE ON TRADE & DEVELOPMENT: THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ENVIRONMENTALLY SOUND TECHNOLOGIES 353, 355 (2000). This Act added GOCO laboratories under the purview of the 1980 Stevenson-Wydler Act, which directed federal agencies to "strive where appropriate to transfer federally owned or originated technology to State and local governments and to the private sector." 15 U.S.C. § 3710(a)(1) (2024).

259. Adam B. Jaffe & Josh Lerner, *Reinventing Public R&D: Patent Policy and the Commercialization of National Laboratory Technologies*, 32 RAND J. ECON. 167, 169 (2001).

260. *See, e.g.*, Lisa Larrimore Ouellette & Rebecca Weires, *University Patenting: Is Private Law Serving Public Values?*, 2019 MICH. ST. L. REV. 1329, 1330; Rebecca S. Eisenberg & Robert Cook-Deegan, *Universities: The Fallen Angels of Bayh-Dole?*, 147 DAEDALUS 76, 78-79 (2018); Mark A. Lemley, *Are Universities Patent Trolls?*, 18 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 611, 611-12, 621 (2008); Arti K. Rai & Rebecca S. Eisenberg, *Bayh Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 289 (2003); Christopher J. Ryan, Jr. & Brian L. Frye, *An Empirical Study of University Patent Activity*, 7 N.Y.U. J. INTELL. PROP. & ENT. L. 51, 55 (2017). For critiques of increasing commercialization of the university more generally, see DEREK BOK, UNIVERSITIES IN THE MARKETPLACE: THE COMMERCIALIZATION OF HIGHER EDUCATION, at x (2003); and JENNIFER WASHBURN, UNIVERSITY, INC.: THE CORPORATE CORRUPTION OF AMERICAN HIGHER EDUCATION, at ix, xii (2005).

Suffice it to say, however, that technology transfer is an enduring feature of the research process at LLNL. A recent study by NNSA quantifying the economic impact of LLNL's technology-transfer programs cataloged over two hundred CRADAs and patent-licensing agreements over a twenty-year period, amounting to substantial economic benefits for the lab and the surrounding economy.[261] However, one way in which the spin-off system at LLNL differs from that of universities is the resulting financial incentives from technology transfer. Whereas Bayh-Dole places no cap on the portion of patent royalties earned by university researchers, Stevenson-Wydler limits national-lab inventors to fifteen percent of those royalties.[262]

As with the NIH IRP, motivations beyond monetary gain and traditional measures of academic achievement thus come into play. In addition to an "inherent desire to do great science and technology," likely shared with industry and academic researchers, lab staff are driven by LLNL's mission to advance national goals through research.[263] In LDRD Director Doug Rotman's view, lab researchers "want to advance the nation" through their scientific work, and projects at LLNL give them a unique opportunity to do so.[264] Patricia Falcone, LLNL deputy director for science and technology, likewise asserts, "[I]t's satisfying to be a part of something where we really are answering questions that come from Washington."[265] LLNL and other national labs are research centers uniquely situated in the national innovation system, and this itself can serve as motivation for high-quality work. Finally, while LLNL researchers do aim to publish their work in peer-reviewed scientific journals, there is less of an institutionally driven need for publications (and later, citations) as one might find in academia. There is instead an emphasis on "doing something useful" and high quality for both the lab and the field in which researchers are working.[266]

III. GOVERNMENT RESEARCH AS AN INNOVATION INSTITUTION

With a clearer understanding of how government research functions in practice, we can now identify some circumstances in which it may be preferable over

261. *National Economic Impacts from the National Nuclear Security Administration and Lawrence Livermore National Laboratory*, NAT'L NUCLEAR SEC. ADMIN. 5-6 (2022), https://www.energy.gov/sites/default/files/2022-04/LLNL%20EIS%20April%202022.pdf [https://perma.cc/T98E-KHJ2].

262. 15 U.S.C. § 3710c(a)(1)(A)(i) (2024).

263. Zoom Interview with Doug Rotman, *supra* note 230.

264. *Id.*

265. Zoom Interview with Patricia Falcone, *supra* note 217.

266. Zoom Interview with Xiaoxing Xia, *supra* note 219.

other innovation institutions. What is government research better at than patents, grants, and other levers? First, we should pause to examine the question itself. What do we mean by "better?" Here, I will answer Brett Frischmann and Mark P. McKenna's invitation for greater clarity of the "normative baseline" in comparative institutional analysis.[267] As Frischmann and McKenna point out, "One cannot evaluate institutions without some sense of what the institutions are supposed to accomplish."[268] Lawyers, however, "generally do not supply the ends" of innovation law and policy.[269] We must therefore assume—perhaps somewhat arbitrarily—the baseline objectives against which we can compare government research with other options.

A. Practical Advantages in Efficient Knowledge Production

A useful point of departure is the normative baseline implicitly in effect across many comparative institutional analyses. This is the framework that Amy Kapczynski labels the "internalist" baseline in the field of IP, which focuses on the efficient production of socially desirable knowledge.[270] This normative baseline is "internal" to IP because it assumes that, in the domain of innovation, patents offer the most efficient means of generating scientific knowledge by aggregating decentralized private information.[271]

However, drawing on a long line of research in economics and legal scholarship, Kapczynski points out that even on these grounds, the relative advantages offered by the patent system remain highly context dependent.[272] Patents may indeed be the most efficient generator of new knowledge from projects in a certain field or those requiring a certain type of research process, but they may be the second- or even third-best option in other settings. No one innovation institution "has absolute efficiency advantages over the others."[273]

The question of relative efficiency, then, is really a search for the *contexts* in which government research can be relied on to produce knowledge more efficiently than other options. In other words, what is the knowledge-production niche in which government research excels? Drawing from the case studies

267. Frischmann & McKenna, *supra* note 16, at 318.

268. *Id.* at 322.

269. *Id.* at 323.

270. Kapczynski, *supra* note 39, at 977-79.

271. *Id.* at 1009, 1017.

272. *Id.* at 988 (noting several important variables that "influence the comparative efficiency of these different systems").

273. *Id.* at 985 (discussing economist Brian Wright's work comparing the relative efficiency advantages of patents, prizes, and grants).

examined above, the following subsections discuss three project attributes—scale, interdisciplinarity, and stability of funding—in which government research has comparative advantages over patents and grants.[274] The unifying theme here is that government research is a more reliable producer of knowledge that requires a high-risk, high-reward research process. As I will show, each of these attributes represents a form of risk that both patent- and grant-driven research tend to avoid.

Importantly, this niche is not limited to any one point on the spectrum from basic to applied research. A traditional conception of the proper role of government research is the "pipeline" model, in which the federal government funds only basic research and "[leaves] to industry the follow-on role of applying that research to practical problems."[275] In practice, federal innovation policymakers have long been preoccupied with the problem posed by the "valley of death" between basic and applied R&D, particularly applied work that can translate into commercial development.[276] Many federal innovation programs support a mix of basic and applied projects, and intramural programs are no exception. Among the two case studies examined above, the NIH describes its niche as encompassing "basic, translational, and clinical research,"[277] and DOE notes that the national labs place "an emphasis on translating basic science to innovation."[278]

1. *Scale*

Government research can support R&D on a scale that universities and industry rarely match. Projects of a massive size are often necessary for fundamental breakthroughs and for the basic infrastructure upon which further advances can be built; "Big Science" is often the recipe for breakthrough science.[279] The

274. I am limiting my comparative discussion to patents and grants because these two are the most sizable real-world drivers of innovation, and I aim to avoid an unwieldy analysis that considers the entire list of innovation institutions (including tax incentives and prizes).

275. William B. Bonvillian, Pioneering Progress: American Science, Technology and Innovation Policy 71 (2024).

276. *Id.* at 92-97.

277. *What Is the IRP?*, *supra* note 127.

278. *National Laboratories*, U.S. Dep't Energy, https://www.energy.gov/national-laboratories [https://perma.cc/E9VP-ZQ3V].

279. Breakthroughs in fundamental physics, for example, often require the largest research facilities in the world: the high-energy particle accelerators of CERN (Switzerland) and Fermilab (Chicago). The term "Big Science" was coined by Alvin M. Weinberg, then-director of Oak Ridge National Laboratory, in an opinion piece in 1961. Weinberg did not provide a definition of the term but noted that the "monuments of Big Science" included "the huge rockets, the high-energy accelerators, the high-flux research reactors." *See* Alvin M. Weinberg, *Impact of Large-Scale Science on the United States*, 134 Science 161, 161 (1961).

means required to do "Big Science"—be that physical equipment or some other form of large-scale investment—are often beyond that which a grant or series of grants could support. The NIH Clinical Center, for example, requires a guaranteed annual budget large enough to provide free care for all patients.[280] This would likely be out of reach for any university or even a consortium of universities mobilizing grant funding. "Big Science" requires concentration and coordination, while the grant system tends to produce decentralization.[281]

Likewise, firms seeking to innovate in the shadow of the patent system usually make the rational calculation against investing in projects of this size. In R&D, scale is inherently linked to risk; since most R&D projects carry some risk of failure, the largest projects are often the riskiest. Consider again LLNL's National Ignition Facility. It would be nearly inconceivable for an R&D-intensive firm to spend over $3 billion constructing a research facility to pursue a new technological field that might pay off decades down the line. "The nature of the scientific instruments demanded by big science," notes historian Robert Kargon and colleagues, is such that "only the federal government has pockets deep enough."[282]

This was not always the case. Large-scale research—much of it focused on fundamental science—was once a hallmark of the nation's leading corporate R&D labs.[283] In the mid-twentieth century, chemical giant DuPont, for example,

280. Clinical Ctr., *Frequently Asked Questions*, NAT'L INSTS. HEALTH, https://www.cc.nih.gov/welcome/faq [https://perma.cc/JMS2-LDS6] (noting that patients at the Clinical Center are treated without charge).

281. One exception might be the NIH's Human Genome Project (HGP), which has been labeled by some observers as an example of successful "Big Science" funded by the government through grants. The HGP was "big," however, only in the total amount of funding committed over several years; the state of genomic sequencing in the 1990s allowed the project to be split up into smaller subprojects carried out by a series of contractors. The NIH's approach differed from that of the original advocates for the project from the Department of Energy, who had proposed sequencing the entire genome in-house at Los Alamos, LLNL, and Lawrence Berkeley national laboratories. NIH leadership, which was then averse to "mindless, Big Science sequencing" of the genome, won the institutional turf war, and the HGP became an extramural undertaking. *See* Daniel J. Kevles, *Out of Eugenics: The Historical Politics of the Human Genome*, *in* THE CODE OF CODES: SCIENTIFIC AND SOCIAL ISSUES IN THE HUMAN GENOME PROJECT 3, 22-25 (Daniel J. Kevles & Leroy Hood eds., 1992); *see also* ROBERT COOK-DEEGAN, THE GENE WARS: SCIENCE, POLITICS, AND THE HUMAN GENOME 141 (1994) (describing the NIH's conclusion before starting the project that it should "eschew Big Science or a crash program").

282. Robert Kargon, Stuart W. Leslie & Erica Schoenberger, *Far Beyond Big Science: Science Regions and the Organization of Research and Development*, *in* BIG SCIENCE: THE GROWTH OF LARGE-SCALE RESEARCH 334, 335 (Peter Galison & Bruce Hevly eds., 1992).

283. David Mowery attributes the rise of large-scale in-house private research to the difficulties in contracting for R&D in the middle of the twentieth century and to the knowledge generation committed massive amounts of resources to do fundamental research at facilities of an enormous scale.[284] But no private patron of "Big Science" looms as large as Bell Labs, the R&D branch of AT&T responsible for ten Nobel Prizes and many of the century's enduring achievements in physics and computer science.[285] In the three decades following World War II, both research-intensive industry leaders and the federal government occupied what would have appeared to be a similar niche: high-risk, "upstream" projects requiring enormous physical facilities and a large staff.[286]

By the 1980s, however, leading firms began a long process of vertical disintegration and downsizing of their in-house R&D programs.[287] Bell Labs, for

that emerges from internal interactions between R&D units and other branches of a company, including production and marketing. *See* David C. Mowery, *The Boundaries of the U.S. Firm in R&D*, *in* COORDINATION AND INFORMATION: HISTORICAL PERSPECTIVES ON THE ORGANIZATION OF ENTERPRISE 147, 149-150 (Naomi R. Lamoreaux & Daniel M.G. Raff eds., 1995).

284. *See* DAVID A. HOUNSHELL & JOHN KENLY SMITH, JR., SCIENCE AND CORPORATE STRATEGY: DU PONT R&D, 1902-1980, at 376-83 (1988) (discussing the activities of DuPont's Central Research Department, an in-house R&D lab tasked with pursuing a basic research program with a broad scope).

285. *See* JON GERTNER, THE IDEA FACTORY: BELL LABS AND THE GREAT AGE OF AMERICAN INNOVATION 32 (2012) ("Jewett [an early Bell Labs president] now commanded an enormous shop. That an industrial laboratory would focus on research and development was not entirely novel; a few large German chemical and pharmaceutical companies had tried it successfully a half century before. But Bell Labs seemed to have embraced the idea on an entirely different scale.").

286. The similarities between industry-leading corporate R&D and government research during this period were many. Several national laboratories were run by corporate R&D leaders as contractors—Bell Labs, for example, served as the contractor of Sandia National Labs for several years. The Bell Labs model also directly inspired organizational choices at LLNL and other national labs in the latter half of the twentieth century. *See* TARTER, *supra* note 208, at 210 (describing a visit by LLNL leadership to Bell Labs in the early 1980s that resulted in "insights into how [Bell Labs] . . . thought about research, how they 'managed' the innovation process, and how they tried to translate the research findings into practical applications—all the same problems that [LLNL] faced"). These parallels were implicitly noted by Amy Kapczynski, who suggested that benefits of government research "might be understood via literature on the nature of the firm and its costs via some of the differences between governments and firms in, for example, their relationships to competition." Kapczynski, *supra* note 39, at 983-84 n.42 (citation omitted).

287. *See, e.g.*, Ashish Arora, Sharon Belenzon & Andrea Patacconi, *The Decline of Science in Corporate R&D*, 39 STRATEGIC MGMT. J. 3, 3 (2018) (finding a dramatic decline in large-scale corporate R&D over the period from 1980-2006). The potential reasons for this decline are many; historian David Hounshell lists changes in antitrust policy, competitive disruptions of the 1970s, the rise of institutional investors, the Bayh-Dole Act and the rise of university start-ups, offshoring of manufacturing, and other potential causes. *See* DUKE UNIV. SCH. OF L., *The Decline in Corporate Research: Should We Worry?* (YouTube, Apr. 5, 2017), https://www.youtube.com/watch?v=mAMZUglH718 [https://perma.cc/G99V-G84Y].

example, was famously broken up in a series of maneuvers by AT&T leadership in the 1980s,[288] and other industrial giants followed suit.[289] While private firms have since expanded their commercial-development efforts and accelerated the patent race, they typically no longer perform large-scale basic research.[290] The withdrawal of private industry from "Big Science" would have left a hole in the national innovation system, had it not been for government research. Intramural R&D today is largely the sole occupant of this niche, and its ability to perform research on a massive scale remains a comparative advantage.

2. *Interdisciplinarity*

Government research programs are also particularly adept at supporting projects that combine expertise from multiple fields. This is significant for several reasons. The interdisciplinary team is an increasingly central contributor to scientific advancement in the twenty-first century, eclipsing the single-field teams and solo inventors of previous epochs.[291] This may be a result of the evolving structural features of scientific inquiry; due to increasing technical sophistication and complexity, many research projects now carry a higher "burden of knowledge" that performers can only overcome by combining insights from multiple fields.[292] Innovation is often a combinatorial process, and synthesizing insights from across fields is one way to generate useful new combinations. Big leaps are often made when concepts from one field are "redomained" into

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288. The breakup followed a landmark antitrust suit brought by the Department of Justice in 1974 and AT&T leadership's eventual agreement to divest many of the company's major branches. *See* GERTNER, *supra* note 285, at 297-303. *Nature* reported that Bell Labs employed only four scientists in 2008. Geoff Brumfiel, *Bell Labs Bottoms Out*, 454 NATURE 927, 927 (2008).

289. See Arora et al., *supra* note 287, at 6; DUKE UNIV. SCH. OF L., *supra* note 287.

290. It is possible that a version of private "Big Science" has been revived by some "Big Tech" companies, in particular for the ongoing private efforts in artificial-intelligence (AI) research. Demis Hassabis, the cofounder of Google's DeepMind, noted tellingly in an interview that he "took inspiration for [DeepMind's] research culture from many innovative organizations, including Bell Labs and the Apollo program." *Q&A: Unlocking Life's Building Blocks*, ATLANTIC (2024), https://www.theatlantic.com/sponsored/google-2023/unlocking-lifes-building-blocks-demis-hassabis/3867 [https://perma.cc/Q78S-74EY].

291. *See* Dan Traficonte & Ben Armstrong, *People Having Ordinary Skills in the Arts*, 37 HARV. J.L. & TECH. 329, 348-52 (2024).

292. Benjamin F. Jones, *The Burden of Knowledge and the "Death of the Renaissance Man": Is Innovation Getting Harder?*, 76 REV. ECON. STUD. 283, 309 (2009). Ben Armstrong and I suggested in earlier work that "[i]t is plausible that in an increasingly complex R&D environment, where the problems to be addressed require additional baseline knowledge, research teams are more commonly required to draw on expertise from different fields." *See* Traficonte & Armstrong, *supra* note 291, at 355.

another and put to new uses.[293] Many of the frontier technological fields today are also inherently interdisciplinary—the field of nanotechnology, for example, is an amalgamation of physics, mechanical engineering, biology, and chemistry.[294]

Interdisciplinarity is recognized not just as a driver of scientific output writ large but also as a key determinant of impact. In general, multidisciplinary team science tends to generate publications with more citations over the long run than single-field work.[295] Patent and publication-citation data have also shown that interdisciplinarity and breakthrough innovations are correlated along a spectrum.[296] As research becomes more interdisciplinary, marked by greater divergence between collaborators' fields of expertise, the likelihood of generating a high-impact, high-value innovation increases.[297] So too does the likelihood of failure, however.[298] Interdisciplinarity thus increases the variance of the outcomes of research projects; it is, like R&D performed at a large scale, a recipe for transformative science at the cost of increased risk. In an era in which

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293. Redomaining is a concept developed by W. Brian Arthur in his work on the history of technology. *See* W. BRIAN ARTHUR, THE NATURE OF TECHNOLOGY: WHAT IT IS AND HOW IT EVOLVES 72-74 (2009). In recent work, Florian Metzler argues that redomaining can and should be an explicit goal of innovation policy in order to promote more radical innovations. *See* Florian Metzler, Radical Technological Innovations and How to Promote Them 19 (June 7, 2023) (unpublished manuscript), https://ssrn.com/abstract=4521978 [https://perma.cc/2M95-MF2C].

294. *See* Lisa Larrimore Ouellette, *Nanotechnology and Innovation Policy*, 29 HARV. J.L. & TECH. 33, 38-39 (2015).

295. *See* DASHUN WANG & ALBERT-LÁSZLÓ BARABÁSI, THE SCIENCE OF SCIENCE 85-86 (2021); *see also* Richard Van Noorden, *Interdisciplinary Research by the Numbers*, 525 NATURE 306, 306-07 (2015) (noting that while over a period of three years, papers with diverse references—that is, those considered interdisciplinary—tend to pick up fewer citations than single-field publications, such interdisciplinary publications have more citations over a thirteen-year period).

296. Lee Fleming, *Breakthroughs and the 'Long Tail' of Innovation*, 49 MIT SLOAN MGMT. REV. 69, 73 (2007) [hereinafter Fleming, *Breakthroughs and the 'Long Tail' of Innovation*]; Lee Fleming, *Recombinant Uncertainty in Technological Search*, 47 MGMT. SCI. 117, 130 (2001); Carolina Castaladi, Koen Frenken & Bart Los, *Related Variety, Unrelated Variety and Technological Breakthroughs: An Analysis of US State-Level Patenting*, 49 REG'L STUD. 767, 776 (2015).

297. Castaladi et al., *supra* note 296, at 776. *But see* Fleming, *Breakthroughs and the 'Long Tail' of Innovation*, *supra* note 296, at 73 (using data from 17,000 patents to find that "the greater the divergence between collaborators' fields of expertise, the lower the overall quality of their output").

298. Castaladi et al., *supra* note 296, at 776. Laura Pedraza-Fariña and Ryan Whalen, citing some of Fleming's work, adopt similar reasoning in their analysis of "network distance" as a predictor of nonobviousness under section 103 of the Patent Act. They posit that the primary cost of performing a "global search"—one that pulls together concepts from distant technological fields—is "assembling a research team with the necessary diverse and deep domain expertise." Laura G. Pedraza-Fariña & Ryan Whalen, *A Network Theory of Patentability*, 87 U. CHI. L. REV. 63, 101 (2020).

breakthrough ideas are "getting harder to find,"[299] this is a type of risk that innovation policy may need to increasingly embrace.

Patents have some role to play in incentivizing interdisciplinary R&D. In previous work, Ben Armstrong and I cataloged a marked increase in patenting by groups of inventors from more than one technological domain.[300] The "distance" between these domains, however, need not be great. Although it is possible that inventions bringing together distant fields are more likely to fulfill the nonobviousness requirement,[301] the legal standards of patentability include no specific incentive for breakthrough interdisciplinary invention. Without doctrinal reform,[302] patent law is likely to remain a weak lever for combining remote fields. The patent incentive may be too blunt a tool to remediate the tendencies in most research communities to pursue low-risk, incremental improvements over radical interdisciplinary work, which Stephanie Plamondon Bair and Laura Pedraza-Fariña call "anti-innovation norms." Addressing IP's inability to overcome these barriers, Bair and Pedraza-Fariña note that

> the IP system is not designed to directly address the social structures of underlying technological communities. To the contrary, IP law is designed to increase the appropriability of those innovations such communities would routinely make were it not for the threat of free riding. The IP incentive, geared as it is towards encouraging the organization as a whole to invest more resources in creative projects generally, leaves it to

299. Nicholas Bloom, Charles I. Jones, John Van Reenen & Michael Webb, *Are Ideas Getting Harder to Find?*, 110 Am. Econ. Rev. 1104, 1134 (2020) (finding a slowdown in breakthrough innovation across a number of fields); *see also* Fabio Pammolli, Laura Magazzini & Massimo Riccaboni, *The Productivity Crisis in Pharmaceutical R&D*, 10 Nature Revs. Drug Discovery 428, 428-29 (2011) (noting a glut in breakthrough innovation in the pharmaceutical sciences).

300. Using patent data, we demonstrated an increase in patents with multiple inventors *and* multiple Cooperative Patent Classification codes. This category of patents increased from forty percent to sixty percent from 1970 to 2020. Traficonte & Armstrong, *supra* note 291, at 353.

301. *Cf.* Pedraza-Fariña & Whalen, *supra* note 298, at 73, 103-05, 109-12 (proposing a standard for nonobviousness based on technological distance).

302. Several legal scholars have proposed reforms to the patentability analysis that would account for the degree to which an invention is interdisciplinary. *See, e.g.*, Michal Shur-Ofry, *Connect the Dots: Patents and Interdisciplinary*, 51 U. Mich. J.L. Reform 55, 76-91 (2017); Laura Pedraza-Fariña, *Patents and the Sociology of Innovation*, 2013 Wis. L. Rev. 813, 861-67; Brenda Simon, *The Implications of Technological Advancement for Obviousness*, 19 Mich. Telecomm. & Tech. L. Rev. 331, 353-61 (2013); Saurabh Vishnubhakat & Arti K. Rai, *When Biopharma Meets Software: Bioinformatics at the Patent Office*, 29 Harv. J.L. & Tech. 206, 238-41 (2015). Ben Armstrong and I proposed a team-based standard of patent law's "person having ordinary skill in the art," which we called the "team having ordinary skills in the art" (THOSITA). A THOSITA would likely have the effect of incentivizing the formation of interdisciplinary teams, since the standard for nonobviousness would be substantially raised. *See* Traficonte & Armstrong, *supra* note 291, at 364-68.

the organization's discretion to choose what types of projects to focus on.[303]

Nor are grants a reliable driver of interdisciplinarity. Studies of grant-application success rates in a number of contexts have shown a pervasive bias in the peer-review process against proposals seeking to draw on distant fields.[304] Reviewers' aversion to interdisciplinary work may stem from the siloed nature of research communities in academia more generally.[305] Aware that this bias persists, grant applicants may adapt their strategies to maximize success rates, reinforcing unidisciplinarity in the process. While there have been some shifts in favor of interdisciplinary work at universities, particularly in the creation of interdisciplinary degree programs,[306] research in these settings is still constrained by the priorities and biases of the grant system. A limited case in which grant funding appears to better embrace boundary-spanning research is the consortium model, in which a large funder commits substantial long-term resources shared between multiple extramural performers.[307] The number of traditionally structured grants awarded each year by the federal government, however, dwarfs that of new consortia.

303. Stephanie Plamondon Bair & Laura G. Pedraza-Fariña, *Anti-Innovation Norms*, 112 NW. U. L. REV. 1069, 1124 (2018) (emphasis omitted) (footnote omitted); *see also* Laura G. Pedraza-Fariña, *The Social Origins of Innovation Failures*, 70 SMU L. REV. 377, 380 (2017) (arguing that innovation failures often stem from structural barriers within social networks).

304. *See, e.g.*, Lindell Bromham, Russell Dinnage & Xia Hua, *Interdisciplinary Research Has Consistently Lower Funding Success,* 534 NATURE, 684, 684-87 (2016) (analyzing 18,476 proposals sent to a major Australian grant program and finding a lower probability of funding success for more interdisciplinary projects); Kevin J. Boudreau, Eva C. Guinan, Karim R. Lakhani & Christoph Riedl, *Looking Across and Looking Beyond the Knowledge Frontier: Intellectual Distance, Novelty, and Resource Allocation in Science*, 62 MGMT. SCI. 2765, 2775-79 (2016) (demonstrating through a controlled experiment that peer reviewers tend to grade proposals less favorably when they include rare combinations of keywords, indicating the degree of interdisciplinarity).

305. *See* Bair & Pedraza-Fariña, *supra* note 303, at 1097.

306. W. James Jacob, *Interdisciplinary Trends in Higher Education*, 1 PALGRAVE COMMC'NS art. no. 15001, at 3 (2015) (noting an increase in "two or more discipline based degrees over the past 40 years").

307. For a discussion of one such consortium and its capacity for spurring interdisciplinary work, see Laura G. Pedraza-Fariña, *Constructing Interdisciplinary Collaboration: The Oncofertility Consortium as an Emerging Knowledge Commons*, *in* GOVERNING MEDICAL RESEARCH COMMONS 259, 259-84 (Katherin J. Strandburg, Brett M. Frischmann & Michael J Madison eds., 2017). Pedraza-Fariña also discusses the success of consortia in the response to COVID-19. *See* Laura G. Pedraza-Fariña, *COVID-19 and Boundary-Crossing Collaboration*, *in* INTELLECTUAL PROPERTY, COVID-19, AND THE NEXT PANDEMIC: DIAGNOSING PROBLEMS, DEVELOPING CURES 86, 86-95 (Haochen Sun & Madhavi Sunder eds., 2024). Price, citing Pedraza-Fariña's work on consortia, identifies interdisciplinarity as a comparative advantage of the grant system relative to patents and prizes. *See* Price, *supra* note 19, at 56-59.

Government research provides a more direct means of supporting interdisciplinary collaborations. A large scientific staff with wide-ranging expertise brought together under a single roof can generate a collaborative research culture without the disciplinary boundaries of traditional academia. Thanks to this internal diversity, intramural programs "have unique access to knowledge from [multiple] communities that do not routinely interact" in other research contexts—a role in the innovation ecosystem that Bair and Pedraza-Fariña identify as "brokers."[308] Interdisciplinary projects can come together organically, as when IRP researchers strike up conversations after "a walk down the hall,"[309] or when LLNL researchers "mingle[] around reactors and accelerators."[310] Intramural programs can also deliberately encourage these projects through specialized initiatives. In either case, risk aversion and disciplinary siloing pose no obstacles to innovation in these contexts; rather, intramural programs actively embrace interdisciplinarity as core to their missions.

Government research can excel at producing interdisciplinary knowledge on a project-by-project basis, but perhaps more significant is its capacity for synthesizing entirely new fields. Describing the early days at the national labs, Westwick notes that while some researchers maintained their disciplinary identities, others did not and "instead submerged their identities and merged their interests," producing new disciplines altogether.[311] Historically, this has meant the production of entire fields whose interdisciplinarity is clear from their names: "biophysics," "bio-organic chemistry," "solid-state science," and so forth.[312] The radical combinations that began in intramural settings were then exported to academia and the private sector. Perhaps the greatest contribution of intramural work to interdisciplinary science is, in Westwick's telling, "the concept of interdisciplinarity itself."[313]

3. *Funding Stability*

The reliable source of funding that government research provides can offer a number of practical advantages. Researchers report a degree of intellectual freedom and risk-taking ability that they would not have in other settings.

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308. Bair & Pedraza-Fariña, *supra* note 303, at 1092 & nn.117-19 (citing Ronald S. Burt, *Structural Holes and Good Ideas*, 110 AM. J. SOCIO. 349, 349-50, 353-55 (2004)).

309. For a discussion of the NIH IRP's internal initiatives to spur interdisciplinary research, see *supra* notes 187-191 and accompanying text.

310. WESTWICK, *supra* note 206, at 307.

311. *Id.* at 59.

312. *Id.* at 306.

313. *Id.* at 307.

Somewhat counterintuitively, government research is the innovation lever with the highest degree of government involvement,[314] but by virtue of its funding mechanisms, it may also offer the researcher a higher degree of intellectual freedom than one might find in a corporate or academic setting. R&D in this context can proceed largely unfettered by the commercial demands that shape corporate research and, as critics of the Bayh-Dole framework have alleged, may encroach on academic science as well. Government research can offer what Richard K. Lester and Michael J. Piore deem "public spaces" – contexts in which innovators can develop ideas through "cooperation, transparency, and disclosure," insulated from the pressures of the competitive marketplace.[315]

R&D conducted in intramural settings might therefore be seen as a variant of "open science" described by social scientists and legal scholars. Unlike commercially oriented innovation, which "converts capital into patents, and back to capital," open science is a model of knowledge production reliant on nonmonetary incentives such as reputational gain.[316] In the standard model, researchers are incentivized to carry out successful projects in order to publish in top peer-reviewed journals, improve their reputation, and secure peer-reviewed grants for future projects.[317]

But this describes the extramural grant system. What motivations drive research when funding is relatively stable regardless of success? Analyzing the Flu Network, a globally dispersed information-sharing network of influenza scientists, Amy Kapczynski notes that while "scientific interest" remains a motivating factor, allocative success in the network also depends on scientists prioritizing "public health importance."[318] The equivalent allocative principle at play in government research, as noted in the case studies, may be the furtherance of an agency's "mission." In the NIH IRP, the pursuit of high-risk, high-reward research may itself serve as that principle. Stable funding in the intramural setting can elevate certain social aims and discourage "projects that . . . may provide the easiest path to striking results[], but that do little to benefit the public."[319]

While stable funding is generally conducive to higher-risk research, it is specifically useful in supporting longer-term projects. Research-intensive firms no longer support the kinds of long-term, open-ended projects that they once did.

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314. For a discussion of the role of the state, see *infra* Section III.B.1.

315. RICHARD K. LESTER & MICHAEL J. PIORE, INNOVATION: THE MISSING DIMENSION 119 (2004).

316. Amy Kapczynski, *Order Without Intellectual Property Law: Open Science in Influenza*, 102 CORN. L. REV. 1539, 1591-92 (2017).

317. *Id.*

318. *Id.* at 1595.

319. *Id.*

Firms do invest substantial resources in R&D—more than ever, as the data suggest—but those investments are increasingly in shorter-term projects further along on the technology-readiness spectrum. This is both a casualty of the decline of large-scale in-house private labs in general,[320] and a symptom of increased short-termism in corporate strategy across the economy.[321] Sarah Keohane Williamson and colleagues have found that long-term projects are "among the first items management teams cut when faced with short-term financial pressures," and that companies have restructured their portfolios to "favor short-term projects delivering more certain, albeit ultimately lower, incremental returns."[322] Successful long-term projects require patient capital, and private R&D managers have grown increasingly impatient.

Grant-supported research can be similarly myopic. Grants, as noted by Price, require applications in the first place and then must be periodically renewed.[323] This works well as an accountability mechanism, since researchers must continue to perform for successful renewals, but it instills in the grant system an aversion to long-term projects.[324] The NIH's flagship R01 grant, among the

320. For a discussion of the decline of large-scale corporate R&D, see *supra* Section III.A.1.

321. *See* Roger L. Martin, *Yes, Short-Termism Really Is a Problem*, HARV. BUS. REV. (Oct. 9, 2015), https://hbr.org/2015/10/yes-short-termism-really-is-a-problem [https://perma.cc/CJ4F-PJQH] (reviewing the various causes of the rise of short-term corporate strategies in the U.S. economy). For economy-wide evidence of increasingly short time horizons in corporate strategy, see Rachelle C. Sampson & Yuan Shi, *Are U.S. Firms Becoming More Short-Term Oriented? Evidence of Shifting Firm Time Horizons from Implied Discount Rates, 1980-2013*, 44 STRATEGIC MGMT. J. 231, 258-59 (2020).

322. Williamson and colleagues quote the head of investor relations at a global telecommunications firm: "We don't invest in anything with a payback period longer than three years." Sarah Keohane Williamson, Ariel Babcock & Allen He, *Funding the Future: Investing in Long-Horizon Innovation*, HARV. L. SCH. F. ON CORP. GOVERNANCE (Aug. 25, 2020), https://corpgov.law.harvard.edu/2020/08/25/funding-the-future-investing-in-long-horizon-innovation [https://perma.cc/UK7X-W2QA].

323. Price, *supra* note 19, at 7, 38.

324. *See id.* at 34-36. A notable exception is the Defense Advanced Research Projects Agency (DARPA), a small (in terms of the number of government employees) and stealthy grant-making agency run by the Department of Defense with a long record of breakthrough successes, including early versions of the internet and autonomous vehicles. The DARPA model—now replicated by other branches of the federal government for energy (ARPA-E), health (ARPA-H), and infrastructure (ARPA-I)—emphasizes longer-term, "high-risk/high-payoff" projects that aim for "change-state" results. *See* Patrick Windham & Richard Van Atta, *Introduction: DARPA—The Innovation Icon*, *in* THE DARPA MODEL FOR TRANSFORMATIVE TECHNOLOGIES: PERSPECTIVES ON THE U.S. DEFENSE ADVANCED RESEARCH PROJECTS AGENCY 1, 14 (William B. Bonvillian, Richard Van Atta & Patrick Windham eds., 2019). While DARPA figures prominently in analyses of postwar federal innovation policy, its annual budget of around $3 billion comprises a small portion of the federal government's total outlays longest-term academic grants available in the federal system, typically covers five years of funding for a major project. Grant-funded researchers can and often do renew their R01 several times by demonstrating continued progress.[325] Applicants would therefore be reluctant to begin a project that may take longer than the grant's renewal period to establish meaningful results. Further, grant renewal can always be denied, leaving a project meant for the long term without any support at all. Dr. Francis Collins summarized this problem as follows:

> [I]f you're thinking of starting a program extramurally, it's not just, "How long [is it] going to take us?" [It's] "What will I have to show for it in my first grant renewal?" . . . [A]nd if you know it's going to be a ten- or fifteen-year project, and you won't see much for seven or eight years, then you're really going to be loath to try to even start in that setting, because you know you're going to get dinged when you come back in four years for that renewal . . . .[326]

Many academics are understandably frustrated with a research system confined by short-term grants, and there is keen interest in a more secure, longer-term form of grant-based funding.[327] One alternative grant-based model is that developed by the Howard Hughes Medical Institute (HHMI), a nonprofit funder of biomedical research with an annual budget of about $800 million.[328] HHMI's leading program is designed to fund "people, not projects."[329] Institute-sponsored investigators receive a single, large grant untethered to any particular

for grant-support R&D. Comparative institutional work confirms that DARPA stands apart from the dominant model of grantmaking at institutions like the NIH and NSF. *See* Michael J. Piore, Phech Colatat & Elisabeth Beck Reynolds, *NSF and DARPA as Models for Research Funding: An Institutional Analysis*, *in* THE DARPA MODEL FOR TRANSFORMATIVE TECHNOLOGIES, *supra*, at 45, 58-59. That DARPA's atypical approach has received so much attention confirms that it is an exception to the standard model in the federal grant system. One way of viewing the DARPA model may be that it has imported certain qualities from government research into the usually more risk-averse grant system.

325. Price, *supra* note 19, at 33-37.

326. Zoom Interview with Francis Collins, *supra* note 10.

327. Celia Ford, *Science Has a Short-Term Memory Problem*, VOX (Sep. 12, 2024, 2:13 PM EDT), https://www.vox.com/future-perfect/370681/science-research-grants-scientific-progress-academia-slow-funding [https://perma.cc/FJZ8-NCPJ].

328. The Howard Hughes Medical Institute (HHMI) reports that it doled out $807 million in fiscal year 2024. *HHMI Fundamentals*, HOWARD HUGHES MED. INST., https://www.hhmi.org/about [https://perma.cc/R6T5-59U9].

329. Price, *supra* note 19, at 53. Price discusses HHMI as a variant of the grant system. *See id.* at 53-54.

line of research so "they can go where their science leads."[330] The funding covers a seven-year period, subject to renewal upon a successful review by qualified external experts in the investigator's field. HHMI's underlying goal is to support "the pursuit of high-risk/high-reward projects" that might not be achievable through the grant system.[331] This is, of course, the exact funding model and underlying philosophy of the NIH IRP. While HHMI is an exception in the extramural world, stable funding is the norm in intramural work, supporting the longer-term projects for which grants are usually a poor fit.

There is, finally, the matter of responsiveness. A stable funding base allows government researchers to pivot quickly when a time-sensitive opportunity arises. One could view this as mitigating another form of risk faced by academia and private industry. Responding immediately to an emerging problem offers the high-reward opportunity to be a pioneer in a new field—think, for example, of Dr. Anthony Fauci's pivot to AIDS research well before the severity of the epidemic was clear.[332] But there is always the possibility that the emerging opportunity dissipates, leaving the researcher with wasted effort. This might deter a private firm from using its limited resources on a risky emerging problem. The first-to-file system for patent priority generally incentivizes inventors to work as quickly as possible on a new venture. An inventor's race to file is limited, however, by the doctrines of utility, enablement, and written description, which force the applicant to demonstrate sufficient progress toward a working and reproducible invention.[333] The space between the initial stage of deciding to pursue a project and the point at which the invention is ready for patenting remains largely unprotected.

Grant-supported research is not exposed to this kind of risk, since funding is ex ante. The problem lies instead with the much slower response time in securing that funding. A typical grant takes well over a year to actually begin funding a new line of research. This ties up the researcher during what can be a critical period for an emerging opportunity, and researchers cannot use preexisting grants to begin work earlier, since these are project specific. The preexisting

330. *Investigator Program*, HOWARD HUGHES MED. INST., https://www.hhmi.org/programs/investigators [https://perma.cc/3F96-AMNV].

331. *Investigator Application Announcement*, HOWARD HUGHES MED. INST. 1 (2022), https://www.hhmi.org/sites/default/files/investigator2024-program-announcement.pdf [https://perma.cc/44TA-T2FR]. One study investigating the performance of HHMI-funded scientists found that they produced high-impact articles at a much higher rate than grant-funded scientists, a result attributed to HHMI's incentive structure. *See* Pierre Azoulay, Joshua S. Graff Zivin & Gustavo Manso, *Incentives and Creativity: Evidence from the Academic Life Sciences*, 42 RAND J. ECON. 527, 530 (2011).

332. *See supra* notes 179-183 and accompanying text.

333. *See* Lisa Larrimore Ouellette, Pierson*, Peer Review, and Patent Law*, 69 VAND. L. REV. 1825, 1831 (2016).

funding that intramural programs provide to researchers works to avoid these delays.

B. Beyond Efficient Knowledge Production

The previous Section discussed the circumstances in which government research can more reliably produce new knowledge than other innovation institutions. Government research is the preferred option when knowledge production requires large-scale, interdisciplinary, and longer-term projects. As other comparative analyses have done,[334] we can also look beyond this efficiency-oriented baseline and bring in other normative frameworks. The choice between generating knowledge through patents, grants, or government research involves more than a calculus of which institutional actor can most efficiently produce that knowledge. Innovation institutions are, in practice, complex tools that implicate values other than efficiency. Again, we can reframe the question: instead of "what is government research better at than patents and grants," we might ask, "what are the values beyond efficiency that government research better addresses?"

A comparative analysis that is "externalist" with respect to normative baselines opens up potentially vast new territory. There is no limit to the kinds of non-efficiency-based concerns that we might analyze here. For practical purposes, I limit this discussion to the two that seem to me to be most salient. The following subsections discuss the relative advantages of government research over patents and grants in two distinct normative domains: the cultivation of state capacity aimed specifically at more effective industrial policy, and the more equitable distribution of the direct economic gains of innovation.

1. State Capacity

State capacity is a core concept in the transdisciplinary literature on global development, particularly in analyses of state-directed economic growth. Though it is a diffuse and contested term,[335] state capacity usually describes in

334. For example, in his analysis of the grant system, Price notes that grants "support the people, institutions, processes, and infrastructure that enable innovation and shape its direction." Price, *supra* note 19, at 50.

335. *See* Miguel Angel Centeno, Atul Kohli & Deborah J. Yashar, *Unpacking States in the Developing World: Capacity, Performance, and Politics*, *in* STATES IN THE DEVELOPING WORLD 1, 3-6 (Miguel A. Centeno, Atul Kohli & Deborah J. Yashar eds., 2017) (noting the competing definitions of state capacity focusing on, in the alternative, "the ability of the state to achieve its own identified goals (*implementation*), the ability of the state to achieve an ideal set of goals usually determined by an outside party (*scope*), the ability of a state to impel citizens and other states to do what they may not have done otherwise (*relational power*), and the organizational competence of the civil servants (*quality of bureaucracy*)").

some general sense the extent to which a government can achieve its goals.[336] The inputs that contribute to this capacity vary depending on the relevant area of policy. In the domain of economic growth and industrial policy, a particular type of statecraft identified as "developmental" is thought to be critical for successful implementation.[337] Capable developmental states—or, at least, the arms of states tasked with carrying out industrial policy—are generally characterized by high levels of technical expertise, effective bureaucratic machinery, and insulation from both political and private rent-seeking.[338] In recent years, there has been increased interest in and, at times, political support for a more robust R&D-oriented industrial policy in the United States.[339] As I will discuss below, there has also been a dramatic backlash against this line of thinking. With state capacity in research now a focus of both reform and reaction, it should be treated as a central externalist consideration in innovation policy.

What capacity is required for the federal government to take a more developmental turn in R&D? At a minimum, the federal government must be capable of influencing the direction of science and technology development in support of public aims.[340] Here, our focus might shift from how to affect the aggregate amount of R&D—simply "more" or "less" of it—to how to shape its direction. A corollary is a shift from a justification of government intervention in R&D rooted in market failure, in which the state fills in gaps on the technological roadmap that the market has laid out, to one based on a conception of public "mission."[341]

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336. An influential definition was provided by political scientist Francis Fukuyama, who cast the term as "the ability of states to plan and execute policies and to enforce laws cleanly and transparently." FRANCIS FUKUYAMA, STATE-BUILDING: GOVERNANCE AND WORLD ORDER IN THE 21ST CENTURY 7 (2004).

337. The term "developmental state" was first coined by Chalmers Johnson in his analysis of Japan's Ministry of International Trade and Industry during that country's "high developmental period" in the postwar years. *See* CHALMERS JOHNSON, MITI AND THE JAPANESE MIRACLE: THE GROWTH OF INDUSTRIAL POLICY, 1925-1975, at 17 (1982).

338. *See* STEPHEN HAGGARD, DEVELOPMENTAL STATES 44-47 (2018).

339. *See* Kapczynski & Michaels, *supra* note 26, at 279, 286-95. Economic sociologists have referred to the federal government's collective set of institutions supporting R&D as the country's "hidden developmental state." *See* Block, *supra* note 28, at 169.

340. Rainer Kattel, Wolfgang Drechsle, and Erkki Karo define capable "entrepreneurial states"—those that play a prominent role in driving technology development in their economies—as "states that are capable of supporting and unleashing necessary innovations in society to tackle important societal challenges (including growth and development) and maintaining broader socio-political stability at the same time." RAINER KATTEL, WOLFGANG DRECHSLE & ERKKI KARO, HOW TO MAKE AN ENTREPRENEURIAL STATE: WHY INNOVATION NEEDS BUREAUCRACY 12 (2022).

341. *See generally* MARIANA MAZZUCATO, MISSION ECONOMY: A MOONSHOT GUIDE TO CHANGING CAPITALISM (2021) (critiquing the limitations of the market-failure framework and endorsing "mission" as an alternative).

Missions are undertaken by the state, often acting in concert with industry and academia, to develop a socially valuable technological field that is sometimes far removed from the direction in which the market seems to be heading.

Research-oriented missions are complex undertakings. The state must possess or have access to deep knowledge of frontier scientific fields and choose from among many promising lines of research.[342] An expert and appropriately incentivized bureaucracy is critical; the state has to be an appealing place for qualified officials to build their careers. In the absence of clear mandates from Congress, state capacity in R&D may also involve the selection of what public goals are to be pursued in the first place. This requires not just a technically proficient bureaucratic enterprise, but also one that can be relied on to serve public values. The state thus needs to preserve its independence. In some cases, both the identification and implementation of these goals may require resistance to private capture.

How does the choice between different innovation levers impact the development of this kind of capacity? Consider patents first. Justifications of the patent system tend to portray the appropriate role of the state in innovation as that of a passive referee. The government's primary task is to apply legal doctrines neutrally through the patent-examination system, making no judgments as to the inventions' substantive usefulness or value to society.[343] Indeed, according to a dominant line of thinking in patent-law scholarship, minimal state action is central to patent law's unique appeal among the set of available levers—perhaps

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342. Dan Breznitz makes similar suggestions in his comparative review of high-tech development policies in Israel, Taiwan, and Ireland:

> [T]he state needs to acquire two assets: (a) sufficient technological and scientific skills, knowledge, and information to make informed decisions in the case of ever more complex industrial technologies development; (b) multiple relationships with the industry that enable the development agencies to be constantly informed about the shape and needs of the industry, as well as to implement its decision without resorting to coercion.

DAN BREZNITZ, INNOVATION AND THE STATE: POLITICAL CHOICE AND STRATEGIES FOR GROWTH IN ISRAEL, TAIWAN, AND IRELAND 31 (2007).

343. To the extent that the patentability analysis ever included a judgment of societal value, it may have been in the now-moribund "beneficial utility" element, which examiners and courts used to invalidate patents deemed to be "injurious to the morals, the health, or the good order of society." Bedford v. Hunt, 3 F. Cas. 37, 37 (C.C.D. Mass. 1817) (No. 1,217). Courts applied this standard intermittently, and the Federal Circuit officially abandoned it in *Juicy Whip, Inc. v. Orange Bang, Inc.*, 185 F.3d 1364, 1366-68 (Fed. Cir. 1999). The modern-utility doctrine requires applicants to demonstrate that the invention at issue does not violate known scientific principles and that it has some real-world use in its current form. *See* JONATHAN S. MASUR & LISA LARRIMORE OUELLETTE, PATENT LAW: CASES, PROBLEMS, AND MATERIALS 168 (2023). This is a calculus much more straightforwardly performed by a neutral, and minimally involved, state arbiter.

more so even than the maximization of efficient knowledge production. According to Peter Menell and colleagues,

> Intellectual property rights have the advantage of limiting the government's role in allocating resources to a finite set of decentralized decisions: whether particular inventions are worthy of a fixed period of protection . . . . By contrast, most other incentive systems, especially large-scale research funding, require central planning on a mass scale . . . . The case for intellectual property rights, then, is based more on a generalized perception of institutional choice than on strong direct evidence of the superiority of intellectual property rights relative to the alternatives.[344]

That the patent system demands—and therefore cultivates—so little state capacity is a feature, not a bug. Amy Kapczynski has pointed toward a counternarrative, noting the complexities dealt with by examiners in applying the legal tests of patentability and by Congress in wading into an "irredeemably complex" area of the law.[345] Even so, this is a form of state capacity as mere competence, useful for the maintenance of the patent system but not for any more ambitious interventions.

The grant system asks more of the state, since government agencies must establish reliable systems for reviewing applications and sometimes articulate long-run priorities,[346] but the leading sources of dynamism remain on the side of the extramural performers. Price notes that most NIH grants are "unsolicited," relying on applicants to "suggest their own projects within very broad parameters."[347] This reflects a "deliberate policy of relying on the judgment of the scientific community" rather than that of the NIH itself.[348] Price analogizes this process of aggregating information from decentralized sources to the patent system, which instead uses price as a valuation mechanism.[349] In both contexts, nonstate actors drive the process. A minority of grants are offered for more narrow subject

344. Peter S. Menell, Mark A. Lemley, Robert P. Merges & Shyamkrishna Balganesh, 1 Intellectual Property in the New Technological Age: 2023, at 28 (2023).

345. Amy Kapczynski, *Intellectual Property's Leviathan*, 77 Law & Contemp. Probs. 131, 140-41 (2014).

346. Summarizing the project-selection system at the NIH, Price notes that "the staff of various institutes and centers are involved in setting priorities to determine what sorts of innovation may be funded, and in crafting the actual RFAs and Program Announcements that formally invite grant applications. And 'the government,' writ large, can influence what areas are funded." Price, *supra* note 19, at 25.

347. *Id.* at 22.

348. *Id.*

349. *Id.* at 21.

areas predetermined by the funding agency.[350] While the state in these cases identifies certain end goals, the means of achieving them are again left to the private performer, roughly akin to the prize system.[351]

There are many clear advantages to the grant system. But what is lost when the federal research complex outsources so much of this critical work? Here we might look to more general critiques of the government's increasing reliance on contractors. In their analysis of the rise of "government by contract," Martha Minow and Jody Freeman note common concerns over waste, lack of accountability, and contractor misconduct,[352] but these may be abated in the R&D context by the grant system's sophisticated processes of selection and monitoring.[353] But Minow and Freeman also contemplate the "cumulative impact of contracting on government capacity and character over the long term" and note the threats of eroding government expertise and increasing difficulties of hiring qualified civil servants.[354] These do seem relevant to the R&D context, since intramural programs require substantial in-house expertise to function and compete with industry and academia for talent.[355] As for contractors as a reliable alternative source of expertise, Rochelle Cooper Dreyfuss warns that "the Bayh-Dole Act has turned many academics into entrepreneurs," making it "harder to find science-policy advisors who appear untainted by their own self-interest."[356]

Like innovation-law scholars, advocates for a more robust state-led approach to innovation often lump grant programs and government research into a single category.[357] But government research may be uniquely well positioned to build and maintain state capacity vis-à-vis science and technology development.

350. *Id.* at 22-23.

351. *Id.* at 23.

352. Jody Freeman & Martha Minow, *Introduction: Reframing the Outsourcing Debates*, *in* GOVERNMENT BY CONTRACT: OUTSOURCING AND AMERICAN DEMOCRACY 2, 4-5 (Jody Freeman & Martha Minow eds., 2009).

353. Nor does the critique that the federal government is outsourcing a "core" state responsibility in a democratic society—such as military operations or criminal justice—seem to apply. *See id.* at 9-14. Since its emergence in the late nineteenth century, government research has always shared the national R&D effort with corporate and academic research.

354. *Id.* at 5.

355. The GOCO model might seem like another form of outsourcing, but as argued in Section II.A.2, *supra*, the organizational features of GOCO-based government research make it virtually identical to government-operated research in practice. GOCO-based research should therefore have the same relation to state capacity-building as the GOGO model.

356. Dreyfuss, *supra* note 38, at 136 (footnote omitted).

357. For example, economist Mariana Mazzucato, a leading proponent of a more "entrepreneurial" role for the state, catalogs and celebrates federal R&D programs in her work but does not attempt to parse out the institutional-design differences between them. For further insight on Mazzucato's views on this question, see generally MAZZUCATO, *supra* note 86.

Government scientists must be technically proficient to obtain their jobs in the first place, and continued performance is ensured by internal review mechanisms. Government research programs are, therefore, reliable reservoirs of the kind of expertise necessary for a developmental approach. Researchers' proximity to the policymaking apparatus is especially useful, since information exchange is more easily facilitated, and the many nonmonetary motivations discussed in the case studies work to ensure that government agencies are not captured by private interests. Government research programs can also cultivate what public-administration scholar Charles T. Goodsell calls "mission mystique," in which public employees "labor not merely to implement laws faithfully or to run programs efficiently," but to "make the most emphatic mark possible on the community and world with respect to their mission."[358] Mission mystique can help recruit and motivate researchers, and thus work to maintain government research programs as sites of high capacity.

As institutions in favorable positions to articulate public aims in R&D, government research programs can serve as a counterweight to science and technology advanced purely by private power. Government research originated in the late nineteenth century in an era when the state "had often been dwarfed by the great corporate domains of the captains of industry."[359] Public institutions performing R&D "renewed the ability of the government to conduct its own business in a society dominated by a complex technology that increasingly depended on research for guidance."[360] In some frontier fields today—most importantly, the emerging field of AI—we see private firms developing the features and uses of new technology in ways entirely dictated by private interests, perhaps even putting the public at risk.[361] Government research could again allow the state to "conduct its own business" in these fields and ensure that they develop in ways that better serve public needs.

The ongoing attacks on federal research by the second Trump Administration, as noted in the Introduction, are part of a broader assault on the state that has gone beyond standard neoliberal suspicions of government and has turned, disturbingly, against expertise writ large.[362] The Administration's stance on

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358. CHARLES T. GOODSELL, MISSION MYSTIQUE: BELIEF SYSTEMS IN PUBLIC AGENCIES 2 (2011).

359. DUPREE, *supra* note 87, at 288.

360. *Id.*

361. *See generally, e.g.*, KAREN HAO, EMPIRE OF AI: DREAMS AND NIGHTMARES IN SAM ALTMAN'S OPENAI (2025) (discussing the history of OpenAI and the various risks overlooked by researchers and company leadership).

362. *See* Tom Nichols, *The Death of Government Expertise*, ATLANTIC (Feb. 17, 2025), https://www.theatlantic.com/ideas/archive/2025/02/career-civil-servant-end/681712 [https://perma.cc/

government research, which appears to follow closely that of the Heritage Foundation's Project 2025, portrays civil-servant scientists—particularly a select few from the NIH—as self-serving liberal activists helping to prop up a "deep state" resistant to conservative reform.[363] Recent cuts to the federal bureaucracy have had a particularly pronounced effect on the NIH and its intramural program, and others may soon follow.[364] The longer-term plan is unclear: perhaps the Administration and its backers want to outsource more R&D to for-profit contractors, or perhaps they believe national competitiveness can be maintained by corporate research alone—a pre-World War II view that all nations with the means to do so have abandoned. Perhaps the plan is simply to strip the government of any and all sources of expertise. Whatever the ends, undoing state capacity in research now appears to be one of the means. Defending and building that capacity should therefore be a goal of a countervailing movement.

2. *Economic Distribution*

A long line of scholars has raised normative objections to the distributive consequences of both patents and grants. These scholars have framed the distributive question not on internalist grounds, such as the efficient distribution of knowledge through patent-disclosure requirements, but rather on broader grounds of distributive justice.[365] Patents are a natural target of this criticism, since they tend to concentrate economic rents among relatively few patent owners and to threaten access to new innovations by resource-constrained consumers.

Turning to grants, an enduring criticism of the Bayh-Dole framework focuses on the distributive logic of technology transfer. Observers have questioned the fairness of allowing private contractors, at first limited to universities and small businesses but later expanded to include larger firms, to own and profit from the patents obtained from publicly funded research. This is sometimes articulated as the "pay-twice" problem: the public pays first for the up-front

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UF6D-UU4L] (arguing that the second Trump Administration's early moves have constituted an "attack against civil servants and the very notion of apolitical expertise"). *See generally* STEPHEN E. HANSON & JEFFREY S. KOPSTEIN, THE ASSAULT ON THE STATE: HOW THE GLOBAL ATTACK ON MODERN GOVERNMENT ENDANGERS OUR FUTURE (2024) (analyzing the unprecedented and increasingly threatening assault on government agencies and the administrative rule of law across the Western world).

363. *See* Roger Severino, *Department of Health and Human Services*, *in* MANDATE FOR LEADERSHIP: THE CONSERVATIVE PROMISE 449, 461-62 (Paul Dans & Steven Groves eds., 2023).

364. Jocelyn Kaiser, *NIH Ban on Renewing Senior Scientists Adds to Assaults on Its In-House Research*, SCIENCE (2025), https://www.science.org/content/article/nih-ban-renewing-senior-scientists-adds-assaults-its-house-research [https://perma.cc/6RFB-M6K7].

365. *See* Kapczynski, *supra* note 39, at 993-95.

research costs, then pays again in the form of supracompetitive prices that the patent enables.[366] In other words, Bayh-Dole "socialize[s] risk" while "privatiz[ing] reward."[367] Others have framed technology transfer simply as a windfall: Senator Russell Long, who had spent much of his career opposing private ownership of publicly funded inventions, called the Bayh-Dole Act at the time of its passage "one of the most radical and far-reaching giveaways" he had encountered.[368] These are all variations of the same basic objection: technology transfer concentrates the rents from public research among a select group of private performers.

At its best, this system delivers indirect benefits from innovations spun out from federally funded research, though research contractors benefit in the most direct way. At its worst, the longer-term political-economy effects of privatizing rewards can work to undermine the very foundations of this system. Subsidizing research conducted by for-profit contractors can contribute to a concentration of economic power that, in the absence of meaningful campaign-finance restrictions, translates seamlessly into political power that can then be wielded against the federal research system. Elon Musk is an obvious example of this

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366. *See, e.g.*, Rebecca E. Wolitz, *The Pay-Twice Critique, Government Funding, and Reasonable Pricing Clauses*, 39 J. LEGAL MED. 177, 178 (2019); Peter Arno & Michael Davis, Opinion, *Paying Twice for the Same Drugs*, WASH. POST (Mar. 27, 2002), https://www.washingtonpost.com/archive/opinions/2002/03/27/paying-twice-for-the-same-drugs/c031aa41-caaf-450d-a95f-c072f6998931 [https://perma.cc/UPM2-WQLV]; Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, 82 VA. L. REV. 1663, 1666 (1996); Bhaven N. Sampat & Frank R. Lichtenberg, *What Are the Respective Roles of the Public and Private Sectors in Pharmaceutical Innovation?*, 30 HEALTH AFFS. 332, 333 (2011). This critique has even made its way into a dissenting opinion of the Supreme Court. *See* Bd. of Trs. of the Leland Stanford Junior Univ. v. Roche Molecular Sys., Inc., 563 U.S. 776, 796 (2011) (Breyer, J., dissenting) ("Why should the public have to pay twice for the same invention?"). For a counterargument to the pay-twice critique, see generally Daniel J. Hemel & Lisa Larrimore Ouellette, *Bayh-Dole Beyond Borders*, 4 J.L. & BIOSCIENCES 282 (2017), which argues that Bayh-Dole's international effect allows the United States to internalize positive externalities from international use of taxpayer-funded inventions and may therefore partly compensate for higher prices.

367. *See* Mariana Mazzucato, Opinion, *We Socialize Bailouts. We Should Socialize Successes, Too*, N.Y. TIMES (July 1, 2020), https://www.nytimes.com/2020/07/01/opinion/inequality-goverment-bailout.html [https://perma.cc/VN7M-SAHW]. In a 2019 House committee hearing, then-freshman Congresswoman Alexandria Ocasio-Cortez questioned why the government is "putting tons of money in the development of drugs that then become privatized, and then they receive no return on the investment that they have made." Lisa Larrimore Ouellette, *AOC on Pharma & Public Funding*, WRITTEN DESCRIPTION (Feb. 3, 2019), https://writtendescription.blogspot.com/2019/02/aoc-on-pharma-public-funding.html [https://perma.cc/NX79-E7V7].

368. Celia W. Dugger, *House Panel Votes Patent Law Change*, WASH. POST (July 25, 1980), https://www.washingtonpost.com/archive/politics/1980/07/25/house-panel-votes-patent-law-change/2b9d944d-ff51-4598-a156-13224facd0d8 [https://perma.cc/ABS7-M5U3].

potential negative feedback loop. Musk's companies have been primary beneficiaries of the federally funded but privately run system, receiving billions in contracts, loans, subsidies, and tax credits over the past twenty years.[369] In the first year of the second Trump Administration, Musk led the Administration's efforts to roll back technology-oriented industrial-policy programs from which he benefited[370] – an unusual way to thank the government and taxpayers for all of their help. While Musk represents an extreme case, he illustrates the risks of an innovation system that tilts too far toward empowering private actors.

The distributive arrangement in effect under the grant system is reshuffled in government research, particularly at GOGO sites such as the NIH IRP. Under Stevenson-Wydler and the Federal Technology Transfer Act, patenting remains an explicit goal of government research, and royalty sharing with named inventors is required. But there is no private entity involved in government research to privatize reward, and the revenue earned from patents flows directly back to the agency that funded the research in the first place. Inventions patented by intramural researchers remain the property of the agencies that funded them.

The example of the critical COVID-19 vaccine research at the IRP's Vaccine Research Center is again illustrative. As a result of the patented breakthroughs led by Drs. Graham and Corbett, the NIH earned back around $700 million in royalty revenues over a two-year period.[371] This amounts to a meaningful portion of the NIH IRP's annual budget of around $5 billion.[372] The NIH uses royalty revenue for a variety of purposes, including further research and training.[373]

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369. Desmond Butler et al., *Elon Musk's Business Empire Is Built on $38 Billion in Government Funding*, WASH. POST (Feb. 26, 2025), https://www.washingtonpost.com/technology/interactive/2025/elon-musk-business-government-contracts-funding [https://perma.cc/PG3A-S8UN].

370. *Id.*

371. Cohen, *supra* note 196.

372. The figure resulting from commercialization of Drs. Graham and Corbett's patent resulted in a substantial uptick in NIH patent revenue. *See Royalty Distribution*, NAT'L INSTS. HEALTH, https://www.techtransfer.nih.gov/metrics/royalty-distribution [https://perma.cc/3RBM-EW3A]. The NIH Technology Transfer Office reports that over the period from 1980 to 2021 (not including revenue from COVID-19 vaccine technology), the NIH earned $1.76 billion in royalty payments. *See Public Health & Economic Impact Study of NIH Intramural Technology Transfer Licensing: Final Project Report*, RSCH. TRIANGLE INST. INT'L 10 (Dec. 2022), https://www.techtransfer.nih.gov/sites/default/files/documents/pdfs/Impact%20Study/NIH%20OTT-RTI%20Final%20Report.pdf [https://perma.cc/KD8J-N9AF].

373. The U.S. General Accounting Office reported NIH royalty funds

> can be used to (1) reward employees of the laboratory, (2) further scientific exchange among the laboratories of the agency, (3) educate and train employees of the agency or laboratory, (4) support other activities that increase the potential for transfer of the technology of the laboratories of the agency, (5) pay expenses

Advocates of Bayh-Dole reform have noted that the shared-revenue model already in place at intramural sites may be more efficient, since it further incentivizes the funding agency to commercialize valuable IP.[374] But the intramural model is also attractive from a normative perspective, since the troubling distributive framework of grant-funded patents is rectified.

Government research can also address a different sort of distributive problem. Since new ideas are easily transported, one line of economic thinking predicts that innovation in one place could generate knowledge "spillovers" that tend to disperse value more broadly across a geographic area.[375]A large body of research has shown, however, that market-driven innovation tends to arise and generate value only in certain places.[376] Innovation "clusters," defined by economist Michael Porter as "geographic concentrations of interconnected companies and institutions in a particular field," result in a mosaic economic geography of highly innovative regions amidst a larger set of lagging ones.[377] While government intervention can play a role in creating clusters in their early stages,[378] their further development is largely driven by firms' rational economic desire to be

> incidental to the administration and licensing of intellectual property by the agency or laboratory, and (6) support scientific research and development consistent with the research and development missions and objectives of the laboratory.

U.S. GEN. ACCT. OFF., GAO-03-829, TECHNOLOGY TRANSFER: NIH-PRIVATE SECTOR PARTNERSHIP IN THE DEVELOPMENT OF TAXOL 8 (2003), https://www.gao.gov/assets/gao-03-829.pdf [https://perma.cc/N848-XB35]. This is a wide-ranging list, amounting essentially to an increase in the general budget of the NIH.

374. *See, e.g.*, Robert S. Danziger & John T. Scott, *Government Royalties on Sales of Biomedical Products Developed with Substantial Public Funding*, 46 J. TECH. TRANSFER 1321, 1322 (2021).

375. *See, e.g.*, David B. Audretsch & Maryann P. Feldman, *Knowledge Spillovers and the Geography of Innovation*, *in* 4 HANDBOOK OF URBAN AND REGIONAL ECONOMICS 2713, 2718 (J. Vernon Henderson & Jacques-François Thisse eds., 2004) (describing the position that "there is no reason that knowledge should stop spilling over just because of borders, such as a city limit, state line, or national boundary"); *cf.* Camilla A. Hrdy, *Patent Nationally, Innovate Locally*, 31 BERKELEY TECH. L.J. 1301, 1307-08 (2017) (pointing out that "[t]he common wisdom is that . . . knowledge produced in one location inevitably 'spills over' to other jurisdictions," but arguing that "research shows that the immediate economic impacts of innovation tend to be highly concentrated in the geographic regions in which it occurs").

376. *See* Hrdy, *supra* note 375, at 1312 (citing ENRICO MORETTI, THE NEW GEOGRAPHY OF JOBS 73-120 (2012)).

377. Michael E. Porter, *Clusters and the New Economics of Competition*, HARV. BUS. REV. (Nov.-Dec. 1998), https://hbr.org/1998/11/clusters-and-the-new-economics-of-competition [https://perma.cc/M9T4-SU25].

378. See, for example, Margaret O'Mara's analysis of the role of the U.S. military in sponsoring the early development of the aerospace cluster in Southern California. MARGARET O'MARA, THE CODE: SILICON VALLEY AND THE REMAKING OF AMERICA 28-29, 36-37 (2019).

physically closer to suppliers and specialized talent pools.[379] Localized innovation begets more localized innovation.[380]

Patent law is national and location agnostic; it offers no solution to innovation-based geographic inequality. Federal research grants offer an appealing alternative. But the grant system, too, can play geographic favorites. At the height of the debate during and after World War II over the future of government-backed R&D, progressive critics of Vannevar Bush's grant-based model worried that an expansion of the extramural system would tend to concentrate research funding in a select group of elite universities in a few geographic areas.[381] Geographic distribution improved in the ensuing decades, but these concerns remain today: the NSF reports a "concentration of R&D spending in a relatively small number of institutions" as a "long-standing characteristic of U.S. academic R&D spending,"[382] and states vary widely in per-capita academic research dollars spent.[383]

Even if grants were to be distributed more evenly, the economic impact of each grant is likely to be limited. The funded research group benefits, but the insulated nature of the university may limit spillovers into the surrounding region. Clusters are field specific, so it would be unlikely for a cluster to develop around a single university, even if grants gave that university an edge in an emerging field. Analyzing state-level innovation policy, Camilla A. Hrdy has suggested that grant programs geared explicitly toward both innovation and expanding the regional economy through job creation often end up supporting only the latter goal.[384] Hrdy even argues that a contradiction may be at play in innovation-oriented programs of this size and scope: since innovation is often job destroying, this type of grant program may be "a snake eating its own tail."[385]

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379. Porter, *supra* note 377.

380. Hrdy, *supra* note 375, at 1314.

381. Senator Harley Kilgore, a staunch New Dealer and Bush's leading rival in the debate over how to structure postwar science policy, put forward an alternative model that would have been more sensitive to the geographic distribution of grant funding. This alternative had support from high-profile progressives at that time, including then-Vice President Henry Wallace. *See* Daniel J. Kevles, *The National Science Foundation and the Debate Over Postwar Research Policy*, 68 ISIS 5, 10-11 (1977).

382. Nat'l Sci. Bd., *Patterns of Academic R&D Spending*, NAT'L SCI. FOUND. (Oct. 5, 2023), https://ncses.nsf.gov/pubs/nsb202326/patterns-of-academic-r-d-spending [https://perma.cc/9J5S-PP47].

383. *See id.*

384. Camilla A. Hrdy, *Innovation or Jobs? An Inconvenient Truth About Public Financing for "Innovation,"* 3 J.L. INNOVATION 69, 75 (2020).

385. *Id.* at 96.

Government research, by virtue of its program size, scope, and stability of funding, may have greater potential to alter the geography of innovation. Studies of the aggregate economic effects of national labs on their regions suggest substantial and lasting impacts.[386] Los Alamos, New Mexico, for example, employs over 24,000 people in the state and brings in an annual $3.12 billion to businesses in the state.[387] The number of jobs directly and indirectly supported by the lab nearly equals the total number of manufacturing jobs in the state. This aggregate impact puts the lab on par with some of the largest research universities in the country.[388]

Intramural programs can impact local economies through sheer size, but can they help develop clusters where none existed before? The limited research on this issue suggests so. In an analysis of the impact of Sandia National Labs on the regional economy in New Mexico, Andrew Schrank concludes that the labs acted as an "*exogenous* source of social and political change" that altered "the growth, character, and consequences of [Albuquerque's] creative class."[389] Schrank suggests that New Mexico developed a major renewables cluster thanks in large part to Sandia's pivot toward clean-energy programs after the Cold War.[390] A new program encouraging lab personnel to spin off their research resulted in a host of highly successful green-energy start-ups all based in the Albuquerque region.[391] The breadth and depth of Sandia's expertise in the field, together with some added incentives promoting lab entrepreneurship, was enough to nudge the region out of fossil-fuel-based development. This case suggests that government research might serve more generally as a regional economic catalyst.

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386. Recent work by Susan Helper, Resem Makan, and Daniel Shoag demonstrates "substantial and persistent differences in patenting activity, retail sales, and individual income growth between counties that hosted national labs and otherwise similar counties that did not." Susan Helper, Resem Makan & Daniel Shoag, *Federally-Funded Science as Engines of Regional Innovation and Prosperity: The Case of the National Labs*, NAT'L BUREAU OF ECON. RSCH. 29 (July 2, 2025), https://conference.nber.org/conf_papers/f225957.pdf [https://perma.cc/P63V-B4UN].

387. Bureau of Bus. & Econ. Rsch., *The Economic Impact of Los Alamos National Laboratory*, U.N.M., at iii (June 2019), https://nuclearactive.org/wp-content/uploads/2021/03/UNMBBER_LANLImpactAnalysis_Revised_101419.pdf [https://perma.cc/L49U-K9AH].

388. Harvard University, for example, employs 18,471 people in Massachusetts and spends $1.7 billion in the state on construction, supplies, and services. *Harvard and the Massachusetts Economy*, HARV. UNIV. 8, 11 (2018), https://community.harvard.edu/files/comm/files/2018_facts_impact_web.pdf [https://perma.cc/C5BG-SWFZ].

389. Schrank, *supra* note 79, at 97.

390. *Id.* at 101-06.

391. *Id.*

C. Drawbacks

Government research, like any innovation institution, is not without limitations. While its distinctive features provide context-dependent advantages, those same features carry potential drawbacks. Understanding these tradeoffs is essential for situating government research within a pluralist innovation system. Other levers in the innovation-law toolkit may be better suited for projects that fall outside the high-risk, high-reward niche in which government research excels. Even when projects demand the scale, interdisciplinarity, and funding stability that government research provides, the choice of this innovation institution involves risks.

One of those risks is politicization. As outlined in the preceding Sections, government research can be more responsive to shifting public needs than corporate or grant-funded research, and it can bolster state capacity for developmental goals. But state capacity can, of course, be weaponized, and public goals can be redefined by those in power to shift radically in antidemocratic or extractive directions. The history of state-performed research in the United States is replete with scientific advances made at devastating human costs, from the scientific expeditions that paved the way for westward expansion into Native lands to Hiroshima. In less extreme cases, conflicts may emerge between a research agency's mission—as handed down from on high—and the epistemic priorities of its scientists. Even absent overt political interference, researchers may feel pressure to conform their work to institutional agendas, leading to distortions in project selection, interpretation of results, or public communication.

Politicization can also undermine one of the most compelling advantages of government research—its stability. Political *in*stability can shift institutional priorities abruptly and erode long-term commitments essential to "patient science." When research programs are subject to sudden realignment or defunding based on electoral turnover or partisan agendas, the continuity required for sustained inquiry becomes fragile. In such environments, researchers may hesitate to embark on ambitious, long-term projects—or may preemptively tailor their work to align with anticipated political preferences, diminishing both the independence and credibility of the enterprise. The Trump Administration's recent funding cuts, along with its reversals on specific research priorities, offer an illustrative example. If government research becomes another policy domain that flip-flops with every new administration, it may be no longer be able to perform its critical function in the innovation system.

This is no reason to abandon government research as an institution, but rather to rethink how it is governed and held accountable to democratic interests. Any public institution carries the risk of falling into the wrong hands. The challenge is to build safeguards that can preserve the integrity of the research enterprise even under political stress. These might include reaffirming internal norms of scientific independence, ensuring transparency in agenda-setting, and creating channels for public oversight. The goal is not to strip research programs of their mission orientation, but to ensure that the missions they serve remain aligned with broadly shared democratic values.

One such norm is likely already built in: as noted above, funding mechanisms at government research programs may actually provide more space for scientist-driven inquiry than the traditional grant system. Without the need to constantly reframe projects to meet the expectations of external funders or peer reviewers, intramural researchers often have greater autonomy to pursue the lines of investigation they deem most important—whether or not those lines align neatly with short-term policy goals. This autonomy can serve as a counterbalance to politicization, preserving a culture of research grounded in scientific judgment.

There is also the potential drawback of waste. Though there are accountability mechanisms at work, government research is likely more tolerant of failure than the grant system and private R&D, and thus more prone to devoting resources to unsuccessful projects. Projects carried out on a large scale and over a longer term further exacerbate this risk. Consider, for example, the research carried out at Livermore's National Ignition Facility. What if the billions of dollars and decades of research spent on fusion-energy research never yielded any breakthroughs like that reached in 2022? What if the development of commercially feasible fusion energy proves impossible? We might be inclined to view these initiatives as wasted resources and effort at a scale that corporate or grant-funded R&D never would have generated.

But failures at this scale are the natural result of a greater emphasis on high-risk, high-reward research. Indeed, by being encouraged to pursue breakthrough innovation, government researchers are *meant* to fail more than their counterparts in other settings. What might appear as waste is better understood as a structural feature of the institution's design. Government research is uniquely positioned to take on the kind of moonshot projects that require sustained investment despite long odds. The challenge, then, is not to eliminate failure, but to build mechanisms for distinguishing between productive and unproductive failure—and to communicate that distinction clearly to the public.

CONCLUSION

Despite the ongoing shake-up of the federal R&D enterprise, government researchers across the country remain hard at work. DOE's national laboratories are advancing new initiatives in clean hydrogen production,[392] supercomputer-assisted scientific discovery,[393] and AI-powered climate modeling.[394] NIH IRP investigators are developing new methods of treating debilitating heart conditions without open-heart surgery,[395] new ways of identifying hidden cancer in pregnant women,[396] and new treatments for life-threatening cases of sepsis.[397] Meanwhile, NASA continues to advance the Artemis program, which aims not only to return humans to the moon but to lay the groundwork for a long-term lunar presence and future missions to Mars.[398]

This Article has provided an analysis of government research as a lever of innovation, examining how it works in practice, what practical advantages it has over other levers, and what normative concerns it implicates. Unlike other institutions in the innovation-law toolkit, government research is uniquely well-suited for high-risk, high-reward projects that are a poor match for private-sector or academic research institutions due to their scale, interdisciplinarity, and requirement of long-term resource commitments. Through institutional mechanisms that enable flexible funding, stable support, and interdisciplinary collaboration, government research serves as a pivotal tool for fostering transformative scientific breakthroughs. This approach complements other innovation levers and has a critical place in the national innovation system.

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Beyond its comparative strengths in specific innovation contexts, government research helps cultivate state capacity and promotes a more equitable distribution of the economic benefits of innovation. By maintaining public ownership of innovation and prioritizing projects that address pressing societal needs, government research can help mitigate geographic and economic inequalities often intensified by both private-sector-driven and grant-funded R&D. As the twenty-first century presents complex technological challenges of the type at which government research excels, its role is poised to grow in importance. For policymakers and scholars, integrating this lever within broader policy frameworks ensures a more robust, equitable, and forward-thinking approach to innovation carried out for the public good.