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### Author
SHIPP, Stephanie S.

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STUDY OF INNOVATION AND TECHNOLOGY IN CHINA

POLICY BRIEF

STI No. 1 December 2013

# The Historical Evolution of STI Policy Decision-making and Key System Characteristics in the United States

Stephanie S. SHIPP

In the United States, science, technology, and innovation (STI)policy-making is a mix of top-down Presidential and Congressional priorities and bottom-up implementation by federal agencies. This paper traces the historic evolution of U.S. STI decision and policy-making and describes characteristics of the system.

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Science, technology, and innovation (STI) policy in the United States can be divided into roughly four periods:

- The first 100 years, from the signing of the constitution to the creation of the first science-based agencies;
- The early to mid-20th century that supported research and development (R&D) to create industry standards, to foster science solutions for wars, and to face the challenge created by the Russian Sputnik, the first artificial Earth satellite launched into space on October 4, 1957;
- Since the 1970s, a focus on the energy and environment as well as policies to accelerate the transfer of technologies from the laboratory to the market; and
- Since 2000, recognition of the importance of science in addressing societal goals and increasing our standard of living, by focusing on increasing funding for science agencies.

These four periods were the result of pivotal changes, from nationhood, wars, threats from other nations, to energy crises, environmental threats, globalization, social media, and terrorism. These periods are outlined in an appendix table that presents a brief overview of U.S. science, technology, and innovation policies.

STI policy began 'officially' in 1787 in the United States when the constitution required the establishment of a system of patents, copyrights, and trademarks. During the 1860s, creation of the land-grant colleges, the National Academies of Science, and the U.S. Department of Agriculture provided important infrastructure for science and science policy that is still relevant today. Many of the science agencies still exist were created in the late 1800s and early 1900s, including the National Institutes of Health, the National Bureau of Standards, and the Naval Research Laboratory. World War II spurred innovation through the creation of the National Laboratories to develop the atom bomb.[1] The Servicemen's Readjustment Act of 1944 (GI Bill of Rights)[2] and Office of Naval Research provided funding for university training and research.[3]

The National Science Foundation was created in 1950. Spurred by the Russians sending Sputnik into space, Congress created the National Aeronautics and Space Administration in 1958 and also significantly increased NSF's budget during the 1958 to 1968 period.

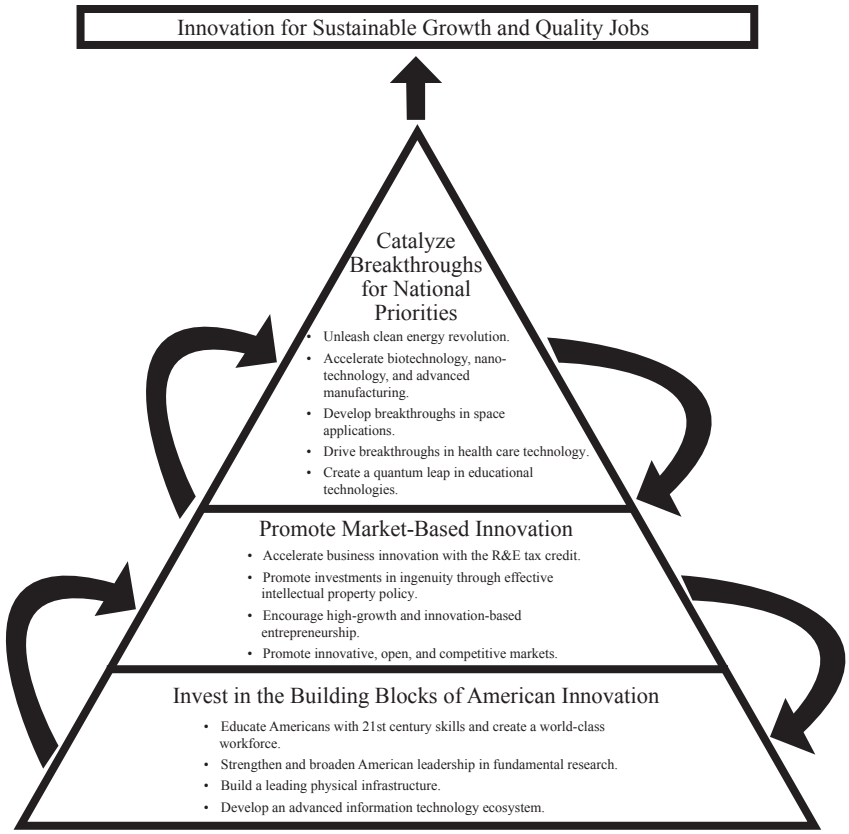
Statistical agencies also rose to prominence during the 1930s and 1940s, although the collection of data began in 1790 with the first census of the population.[4] Although not generally included in STI policymaking, in fact, national statistics on industry trends, employment, occupations, educational status, and other topics inform STI policymaking. The Bureau of Labor Statistics began in 1884; today there are 13 principal statistical agencies and dozens of other smaller ones.[5] The NSF National Center for Science and Engineering Statistics is now the provider of the main science and engineering indicators through their National Patterns Surveys and Science and Engineering Indicators, a compilation of variety of national and international statistics published every two years.[6]

During the 1970s, the focus was on creating agencies and legislation to improve the environment and develop new sources of energy. During the 1980s, there was interest in creating mechanisms to accelerate the transfer of technologies from the laboratory to the marketplace and the creation of public-private partnerships. The passage of the Bayh-Dole and Stevenson-Wydler Acts in 1980 put technology transfer on the map for universities and federal laboratories.[7] The 1988 Omnibus Trade and Competiveness Act, passed by Congress in response to increased competition from Japan, led to the creation of new public-private partnerships, including the Advanced Technology Program and the Manufacturing Extension Partnership at the National Institute of Standards and Technology (NIST), renamed from the National Bureau of Standards to represent the increased focus on technology development and manufacturing.[8]

Since 1999, the focus has been on increasing science funding, first at the National Institutes of Health, and since 2008 at the other science agencies. In 2007, Congress enacted the America COMPETES Act (Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science), which focused on increasing funding in the physical sciences and renewed focus on education in sciences and related disciplines. As part of the COMPETES Act, Congress legislated new programs, such as the Advanced Research Projects Agency-Energy (ARPA-E), which is modeled on the successful Defense Advanced Research Projects Agency (DARPA) program, and focuses on development of new energy technologies.[9] The 2009 American Reinvestment and Recovery Act supported innovation, education, and infrastructure, and the America Invents Act revised our patent system to grant patents to a "first inventor to file" system from a "first to invent."

## KEY FACTORS SHAPING THE DYNAMICS OF THE STI DECISION-MAKING SYSTEM

In the United States, STI policymaking is a mix of top-down Presidential and Congressional priorities and bottom-up implementation by federal agencies. President Obama's "Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs" (see Figure 1) provides top-down guidance to agencies that then use their knowledge and interpretation of the mandates to run existing programs and implement new ones.[10]




*Source:* The White House, "Strategy for American Innovation: Executive Summary," 2011, http://www.whitehouse.gov/innovation/strategy/executive-summary.

**Figure 1.** Strategy for American Innovation

One example of a top-down Presidential initiative can be found in a recent speech in which President Obama called on companies, research universities, foundations, and philanthropists to identify and pursue Grand Challenges:

> Grand Challenges are ambitious but achievable goals that harness science, technology, and innovation to solve important national or global problems and that have the potential to capture the public's imagination.[11]

Grand Challenge initiatives may involve some government funds but also rely on the persuasive powers of the president to convince companies, universities, and agencies to work together on complex, large-scale problems. For example, the National Nanotechnology Initiative (NNI) that was announced by President Clinton in 2000 had spillover effects in that major universities, venture capitalists, entrepreneurs, states, and Fortune 500 companies launched new efforts in nanotechnology research. The goal of such challenges is that federal funding will spark additional investments by others, which is what the NNI did.

Recent Grand Challenges include the BRAIN (Brain Research Through Advancing Innovative Neurotechnologies) initiative announced in February 2013, and the Materials Genome Initiative (MGI, to advance materials discovery) announced in 2011, which are expected to inspire multiple stakeholders to invest in research over and above federal investments.[12] Large federal initiatives, such as the NNI, BRAIN, and MGI, provide research dollars to areas that are underfunded in the private sector and support research to achieve a solution to a societal goal, but do not prescribe how to do it.

The federal government not only creates innovation policy but must also be innovative itself. In July 2013, President Obama directed agencies to innovate.[13] Three recent examples follow:

- To improve transparency in federal government operations, the Open Government Directive requires federal agencies "to take immediate, specific steps to achieve key milestones in transparency, participation, and collaboration."[14] Through a number of initiatives, the federal government makes available how agencies allocate their funding with websites like recovery.gov, USASpending.gov, and IT.usaspending.gov.
- The federal government seeks input from the public through crowdsourcing techniques that seek input on specific topics. For example, there was a request for ideas for shaping the Federal Emergency Management Agency's vision for emergency management and the National Dialogue on the Federal Mobile Strategy in January 2012.[15]
- OSTP and other agencies are using blogs, Twitter, and other social networking mechanisms to discuss STI policy and seek public input, in addition to traditional Federal Registrar Notices and Requests for Information.[16]

## CHARACTERISTICS OF U.S. STI POLICY DECISION-MAKING

### *The Federal Role in STI as Investor, Customer, Partner, and Regulator*

The government generates demand for high technology goods and supports these through investment, procurement, and partnerships. There are many examples of these government/industry interactions, beginning early in American history. In

1798, the federal government contracted with the inventor Eli Whitney for interchangeable musket parts. In 1842, Congress appropriated funds to develop and prototype Samuel Morse's telegraph. Both of these innovations, with federal support, led to new industries.[17]

The government invested heavily in computer technology during World War II and played a key role in creating the first electronic digital computers, ENIAC. They continued this funding of high-risk research through several agencies, including the Office of Naval Research, the National Science Foundation, the Public Health Service, and the National Bureau of Standards. These federal investments were critical to the development of the computer industry.[18] Since then, federal investments in biotechnology, microelectronics, and advanced materials have led to the creation of new industries. The key to U.S. STI policy is the centrality of the firm in continuing and complementing research initiated by the federal government and in deployment to the market.

As early investor, the government identifies and funds emerging areas of research or early stages of technology development. These investments provide greater incentives to the academic and private sectors to invest in higher-risk R&D to achieve societal goals than would occur without government action. As leading customer, the government provides guaranteed first purchases for a product or group of products. As partner in public-private partnerships, the government jointly funds and operates projects that would not otherwise be initiated within any single sector. During World War II, for example, there were "major collaborative initiatives in pharmaceutical manufacturing, petrochemicals, synthetic rubber, and atomic weapons."[19] Many of these military technologies were converted to civilian applications after World War II. As regulator, the government's role is also to provide regulations to ensure that pursuit of profit by the private sector does not interfere with social welfare. These regulations compel or influence consumers, businesses, and other levels of government to expend resources in certain ways. Government action often supports and encourages innovation as it reduces risk and uncertainty, whether the government action is in the form of incentives or regulations.

### *Commitment to STI*

Commitment to STI is often represented by the R&D intensity (R&D/gross domestic product) metric. In the United States, R&D intensity was 2.9 percent in 2009 and has fluctuated between 2.6 percent and 2.8 percent during the past 10 years. This level places the United States close to the 3 percent level proposed by the European Union in 2000 and called out as a U.S. goal by President Obama in 2009.[20] The private sector accounts for about 70 percent and the U.S. government about 30 percent. The United States spends the most on R&D, accounting for 31 percent of world R&D, although it is ranked eighth in R&D intensity after Israel, Sweden, Finland, Japan, South Korea, Switzerland, and Taiwan. China's ratio of 1.7 percent has more than doubled, from 0.8 percent in 1999.[21]

### *Evidence-Influenced Policy for STI Decision-making*

There have been many attempts to systematically measure the performance of federal programs, such as the 1993 Government Performance and Reform Act (GPRA) and the Program Assessment Rating Tool (PART) in the early 2000s. In theory, these measures are used to guide budget decisions.[22] Recent guidance such as OMB Circular A-11 and the 2010 GPRA Modernization Act) directs agencies to "describe the targeted outcomes of research and development (R&D) programs using meaningful, measurable, quantitative metrics where possible and describe how they plan to evaluate the success of those programs."[23] New initiatives such as Science of Science and Innovation Policy and STAR Metrics are attempting to build methods, tools, and new sources of data to provide analyses for use by policymakers.[24] These programs are not yet widely adopted, but once they are, they could provide new methods for influencing policy.

There are two alternative views about the value of providing evidence as a basis for policymaking. The first focuses on the value of evidence as part of the discussion. Policy is "best understood as a form or policy argument or practical reasoning that is persuasive with respect to the benefit or harm of policy actions … [thus] evidence-influenced politics is suggested as a more informative metaphor, descriptively and prescriptively, than evidenced-based policy."[25] The second argues for policies and programs funding a broad array of high-risk research, recognizing that failure is a part of this, and thus taking a portfolio approach is important. "Focusing resources on areas that are deemed impactful, while ignoring many others, decreases diversity, making science less productive."[26]

### *Federal Budget Cycles*

The budget process in the United States is not conducive to long-run planning. The annual budget cycle increases uncertainty and makes it difficult to run programs consistently. Often, agencies cannot spend new money until appropriations are approved, which often occurs several months into the fiscal year. Increased multi-year funding of programs would reduce this uncertainty and "lumpiness" in spending. In addition, while some agencies such as Department of Defense and the National Institutes of Health have sufficient budget and capacity to support mission-related R&D, many others lack the resources to do this, such as Departments of State, Labor, Housing and Urban and Development.[27] In some areas this

is changing. For example, NIST received multi-year funding for their National Network for Manufacturing Innovation Institutes.[28]

### *A Robust Statistical System*

The U.S. Statistical System involves more than 100 agencies with direct funding for statistical activities of $500,000 or more, defined by OMB to include not only survey and census design and data collection but also analysis of the data.[29] As employment patterns and occupational choices change over time, improving our ability to accurately track changes is critical. The statistical system has to balance maintaining comparability of its surveys over time with agility in capturing new trends, such as the focus in defining and measuring trends in science, technology, and innovation related sectors. Some measurement issues may be difficult to grapple with, such as tracking educational training, occupational choices, and career trajectories. For example, there is interest in how many engineers are trained in the United States in comparison to China, but measurement issues abound. Each country defines who is an engineer differently, making comparisons challenging. While the decline in manufacturing workers is of concern to policymakers, it would be helpful to decompose the changes into those that have resulted from increases in productivity versus declines in demand, *or* changes in the sectors in which employees are counted. We need to provide a comprehensive way of managing manufacturing data so policymakers have improved data at their fingertips.

Another area of interest is how new sources of data might be used to measure trends. This includes new ways of measuring what is important, such as the role of intangibles in the economy. The recent release of the revised gross domestic product estimates that now count R&D as an investment rather than an expense are a first step in measuring intangibles.[30] The Big Data Initiative is focusing on how trends in science, technology, and innovation might be better tracked using alternative sources.[31] One example of an emerging area of focus for policymakers is the role of big data in understanding how to create more efficient and livable cities.[32]

### *Celebrating STI Successes*

Celebrating successes can inspire others to undertake challenging and high-risk STI activities. Private-sector programs such as Space X, Grand Challenges, and FIRST celebrate science, technology, engineering, and math and encourage participation by companies, students, and individuals.[33] In addition, the federal government gives some awards such as the Malcolm Baldrige National Quality Award for performance excellence while offering criteria, assessments, tools, training, and community through a program dedicated to helping applicant organizations improve.[34] However, awards for STI are few and far between. As Kent Hughes, director of the Science, Technology, America, and the Global Economy program at the Woodrow Wilson International Center for Scholars, lamented, "Countries get what they celebrate. We are awash in technology and yet seem to lack a popular curiosity about who invented it, who made it, or how it works."[35]

## CONCLUSION

This paper traces the historic evolution of U.S. STI decision and policymaking as well as describes characteristics of the system. Each of the characteristics highlight positive aspects of the STI system. Briefly, these characteristics are

- The federal government's role as investor, customer, partner, and regulator
- Commitment to STI
- Evidence-influenced policy for STI decision-making
- Federal budget cycles
- A robust statistical system
- Celebrating STI successes

The U.S. system is a leader in STI decision-making yet we have much to learn from other countries as their systems develop and evolve. To continue to succeed, these characteristics also provide a road map for going forward.

## **Appendix:** A Brief Historical Overview of U.S. Science, Technology, and Innovation Policies

### Getting Started: The First Century of Science Policy in the United States

| | |
|---|---|
| 1787 | Article 1, Section 8 of the U.S. Constitution led to system of patents, copyrights, and trademarks |
| 1790 | Article I, Section 2 of the U.S. Constitution led to the collection of the first population census |
| 1862 | Morrill Act created system of land-grant colleges |
| 1862 | National Academies of Science |
| 1862 | Department of Agriculture |
| 1879 | United States Geological Survey |
| 1884 | Bureau of Labor Statistics |
| 1887 | National Institutes of Health |
| 1887 | Hatch Act and 1907 Adams Act: Experimental Agricultural Centers |

### Early to Mid-Twentieth Century: From Standards to War to Sputnik

| | |
|---|---|
| 1901 | National Bureau of Standards |
| 1925 | Veterans Health Administration Office of Research and Development |
| 1923 | Naval Research Laboratory |
| 1943 | WWII—Creation of top secret labs, such as LANL (1943), ORNL (1943), Sandia (1945), BNL (1947) |
| 1943 | The Servicemen's Readjustment Act of 1944 ( GI Bill of Rights) |
| 1946 | Office of Naval Research |
| 1950 | National Science Foundation |
| 1950 | Air Force Office of Scientific Research |
| 1953 | Agricultural Research Service |
| 1957 | National Aeronautics and Space Administration |
| 1958 | National Defense Education Fellowship (funding for post-doctoral work in the sciences and study of foreign languages) |
| 1958 | Advanced Research Projects Agency, later renamed DARPA |
| 1958 | First President's Science and Technology Advisor, James R. Killian |

### Since the 1970s: Energy, Environment, Technology Transfer, and Partnerships

| | |
|---|---|
| 1970 | National Oceanic and Atmospheric Administration |
| 1970 | Environmental Protection Agency |
| 1977 | Department of Energy |
| 1980 | Stevenson-Wydler Technology Innovation Act |
| 1980 | Bayh-Dole University and Small Business Patent Act |
| 1981 | Research and Experimentation Tax Credit |
| 1982 | Small Business Innovation Research Program |
| 1987 | SEMATECH: Consortium designed to strengthen U.S. semiconductor industry |
| 1988 | Omnibus Trade and Competiveness Act (creation of new public-private partnerships—Advanced Technology Partnership and Manufacturing Extension Partnership) |
| 1992 | Army Research Lab; Army created first research labs in 1820 |
| 1997 | Air Force Research Lab; Air Force created first research labs in the 1940s |

### Since 1999: An Increased Focus on Science Funding

| | |
|---|---|
| 1999–2003 | Doubling of NIH budget |
| 2003 | Science and Technology Directorate of the Department of Homeland Security |
| 2007 | America Competes Act (Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science); renewed in 2010 |
| 2008 | National Institute of Food and Agriculture |
| 2009 | Advanced Research Projects Agency-Energy (ARPA-E) |
| 2009 | American Reinvestment and Recovery Act |
| 2011 | America Reinvents Act |

*Source:* Data from Axel Werwatz and Kent Hughes, "Part One: Innovation in the United States and Germany." *AICGS Policy Report* 26, June 2006, American Institute for Contemporary German Studies, Johns Hopkins University.

## *Endnotes*

1. The national labs are still responsible for maintaining our nuclear stockpile; however, their missions have evolved since the 1940s; now these laboratories are also responsible for R&D related to national security and for achieving societal goals.
2. Benefits included low-cost mortgages, low-interest loans to start a business or farm, cash payments of tuition and living expenses to attend college, high school or vocational education, as well as one year of unemployment compensation. It was available to every veteran who had been on active duty during the war years for at least ninety days and had not been dishonorably discharged; combat was not required. By the end of the program in 1956, roughly 2.2 million veterans had used the G.I. Bill education benefits in order to attend colleges or universities, and an additional 6.6 million used these benefits for some kind of training program. http://www.gibill.va.gov/benefits/history_timeline/index.html.
3. The Office of Naval Research (ONR) is the office within the United States Department of the Navy that coordinates, executes, and promotes the science and technology programs of the U.S. Navy and Marine Corps through schools, universities, and government laboratories, nonprofit, and for-profit organizations.
4. The United States Census is a decennial census mandated by the Constitution: Article I, Section 2, says, "Representatives and direct Taxes shall be apportioned among the several States ... according to their respective Numbers ... The actual Enumeration shall be made within three Years after the first Meeting of the Congress of the United States, and within every subsequent Term of ten Years." See www.census.gov.
5. See "Federal Agencies with Statistical Programs" (http://www.fedstats.gov/agencies/) for a listing of the 95 statistical agencies or programs that collect statistics for their agency.
6. See Appendix B in Technology Transfer and Commercialization Landscape of the Federal Laboratories, IDA Paper NS P-4728, June 2011, https://www.ida.org/upload/stpi/pdfs/p-4728nsfinal508compliantfedlabttcreport.pdf; and Science and Engineering Indicators, 2012, http://www.nsf.gov/statistics/seind12/
7. Axel Werwatz and Kent Hughes. "Part One: Innovation in the United States and Germany," *AICGS Policy Report* 26, June 2006, American Institute for Contemporary German Studies, Johns Hopkins University.
8. See Chapter 4 in "White Papers on Advanced Manufacturing Questions" for a description of the ATP program. http://www.whitehouse.gov/sites/default/files/microsites/ostp/advanced-manuf-papers.pdf.
9. ARPA-E advances high-potential, high-impact energy technologies that are too early for private-sector investment. See http://arpa-e.energy.gov/?q=arpa-e-site-page/about.
10. See National Economic Council, "A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs," September 2009, http://www.whitehouse.gov/administration/eop/nec/StrategyforAmericanInnovation/; and "A Strategy for American Innovation: Securing Our Economic Growth and Prosperity," http://www.whitehouse.gov/innovation/strategy.
11. Office of Science and Technology Policy, "21st Century Grand Challenges," http://www.whitehouse.gov/administration/eop/ostp/grand-challenges.
12. Office of Science and Technology Policy, "President Obama Launches the 'BRAIN' Initiative," April 2, 2013, http://www.whitehouse.gov/blog/2013/04/02/president-obama-launches-brain-initiative; National Science and Technology Council, "Materials Genome Initiative for Global Competitiveness," June 2011, http://www.whitehouse.gov/sites/default/files/microsites/ostp/materials_genome_initiative-final.pdf.
13. Steve VanRoekel and Todd Park, "A Smarter, More Innovative Government for the American People," July 8, 2013, http://www.whitehouse.gov/blog/2013/07/08/smarter-more-innovative-government-american-people.
14. Open Government Initiative, "About Open Government," http://www.whitehouse.gov/open/about.
15. On crowdsourcing, see Craig Fugate, "Crowdsourcing Solutions to Prepare Our Communities," November 2, 2010, http://www.whitehouse.gov/blog/2010/11/02/crowdsourcing-solutions-prepare-our-communities. The National Dialogue on the Federal Mobile Strategy sought input from January 11 through January 27, 2012 and received hundreds of votes and ideas. See the results at http://mobility-strategy.ideascale.com/a/pages/analytics.
16. Federal Register Notices announce and seek feedback on four categories of announcements. These are 1) non-rulemaking documents such as notices of public meetings, hearings, investigations, grants and funding, environmental impact statements, information collections, statements of organization and functions, delegations, and other announcements of public interest; 2) proposed regulations, such as agencies' plans to solve problems and accomplish goals, and give interested persons an opportunity to submit comments to improve the final regulation; 3) regulations that apply to the general public and have final legal effect; and 4) documents signed by the President of the United States, such as Executive Orders, Proclamations, Administrative Orders, Presidential Memoranda, and other issuances of the President that are required or directed to be published in the Federal Register. Office of the Federal Registrar, "What's in the Federal Register" https://www.federalregister.gov/.
17. D. Hounshell, *From the American System to Mass Production: 1800–1932* (Baltimore, MD: Johns Hopkins University Press, 1985).
18. K. Flamm, *Creating the Computer* (Washington, DC: Brookings, 1988).
19. D. Mowery, "Collaborative R&D: How Effective Is It? *Issues in Science and Technology* (fall 1998).
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21. National Science Foundation, "Science and Engineering Indicators 2012," http://www.nsf.gov/statistics/seind12/.
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24. On NSF's SciSIP, see http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf13104. STAR METRICS™ (Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness and Science) is a multi-agency venture led by the National Institutes of Health, the National Science Foundation (NSF) and the White House Office of Science and Technology Policy (OSTP). See https://www.starmetrics.nih.gov/
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27. T. Kalil, "A Broader Vision for Government Research," *Issues in Science and Technology* (spring 2013).
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30. P. Coy, "Intangible Investment Rewrites Economic History as GDP Meets R&D," July 18, 2013, Bloomberg.com.
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**Stephanie SHIPP** is an adjunct research staff member at IDA Science and Technology Policy Institute and Deputy Director and research professor at the Social and Decision Analytics Laboratory, Virginia Bioinformatics Institute at Virginia Tech.