An Analysis of Efforts to Double Federal Funding for Physical Sciences and Engineering Research

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Summary

Federal funding of physical sciences and engineering (PS&E) research has played a substantial role in U.S. economic growth and job creation by creating the underlying knowledge that supports technological innovation. Some Members of Congress and leaders in industry and academia have expressed concern that recent public investments in these disciplines have been inadequate in light of the emergence of new global competitors and the science and technology-focused investments of other nations. A 2005 National Academies report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, requested by several Members of Congress, recommended doubling federal basic research funding over seven years, with an emphasis on selected fields, including PS&E, to address this issue.

President George W. Bush subsequently launched the American Competitiveness Initiative, which sought, in part, to double funding over 10 years for targeted accounts at three federal agencies with a research focus on physical sciences and engineering—the National Science Foundation, the Department of Energy's Office of Science, and the Department of Commerce's National Institute of Standards and Technology. In 2007, Congress enacted the America COMPETES Act (P.L. 110-69) which set authorization levels for FY2008-FY2010 for the targeted accounts that established, implicitly, a seven-year doubling path. Subsequently, Congress passed the America COMPETES Reauthorization Act of 2010 (P.L. 111-358), setting FY2011-FY2013 authorization levels for these accounts that implicitly extended the doubling path to 11 years. In his FY2010 budget, President Obama supported a 10-year doubling effort, but in subsequent budgets he first extended the doubling period then omitted the doubling language. Opposition to the doubling effort has centered primarily on concerns about increased spending in light of current economic conditions. Some contend that additional research funding may not translate effectively into U.S. innovation and that scarcity of funds elicits stronger research proposals.

Progress toward doubling the targeted accounts has been slower than originally sought. Through FY2010, Congress had appropriated funding for the targeted accounts consistent with doubling over 12 years. However, by FY2013 appropriations for these accounts had fallen by 1.8% from their FY2010 level, extending the doubling pace to more than 22 years. Some policymakers are currently seeking to address the perceived need for increased funding for PS&E using a framework that supports sustained and predictable increases rather than using a doubling goal.

And while the doubling agencies were targeted to raise overall federal spending on PS&E basic research, obligations for PS&E basic research at these agencies grew from FY2006 to FY2013 at a slower pace (3.6% CAGR) than at all other agencies (4.9% CAGR). Total federal obligations for PS&E basic research grew faster between FY2006 and FY2013 (4.2% CAGR) than in the prior decade (2.8% CAGR). However, total federal obligations for PS&E applied research grew at a slower pace (2.0% CAGR) between FY2006 and FY2013 period than in the prior decade (4.7% CAGR), as did total federal PS&E research (3.0% CAGR and 3.9% CAGR, respectively).

Congress has a variety of options related to the doubling effort, including providing more funds for the targeted accounts; changing existing funding to better align with overarching goals of the doubling effort (e.g., national competitiveness, economic growth, job creation); shifting PS&E applied research and development funding to PS&E basic research; identifying and adopting new mechanisms to promote expanded cooperative research and technical collaboration among industry, academia, government, and others, and more effective approaches to technological innovation; exploring other mechanisms for meeting the economic goals of the doubling effort by further incentivizing private sector efforts; identifying and adopting mechanisms by which the United States might promote increased access to and use of PS&E research performed in other nations; accepting a slower doubling path; or delaying or abandoning the effort.

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Introduction

A decade ago, concerns about stagnation in federal funding for physical sciences and engineering research and its potential effects on U.S. innovation, competitiveness, and job creation led to long-term efforts to increase funding for these disciplines. Since the appropriations process does not specify funding for specific scientific and engineering disciplines, executive and legislative efforts focused on doubling funding for certain appropriations accounts that support research in these disciplines.[1] These accounts (the "targeted accounts") were the National Science Foundation (NSF), the Department of Energy (DOE) Office of Science, and the laboratory and construction accounts of the Department of Commerce National Institute of Standards and Technology (NIST).

Advocates put forward a variety of arguments supporting the doubling effort. These arguments emphasized the importance of research in enabling U.S. economic growth, job creation, global scientific and technological leadership, innovation, and industrial competitiveness. Opposition to the doubling effort focused primarily on a reluctance to rapidly increase federal expenditures, especially in light of the nation's federal fiscal condition, deficit, and debt. Some contended that additional research funding may not translate into increased innovation and that scarcity of funds may elicit stronger research proposals due to increased competition.

Starting in 2006, successive Congresses and Presidents sought to substantially increase federal funding for physical sciences and engineering (PS&E) research. A key characteristic of the doubling effort was the time period over which the doubling was to occur.[2] Policymakers put forward a variety of timeframes:

- In February 2006, President George W. Bush proposed a 10-year doubling period in his American Competitiveness Initiative (ACI), using FY2006 as the base year (in other words, aggregate FY2016 funding for the targeted accounts was to be twice as large as in FY2006).[3]
- In 2007, the America COMPETES Act (P.L. 110-69) authorized appropriations for the targeted accounts for FY2008-FY2010 at levels consistent with a seven-year doubling pace.
- The America COMPETES Reauthorization Act of 2010 (P.L. 111-358) set authorization levels for the targeted accounts for FY2011-FY2013 consistent with doubling over approximately 11 years.
- President Barack Obama affirmed a 10-year doubling period in his FY2010 budget (anticipating completion in FY2016), revised it to an 11-year doubling period in his FY2011 budget (proposing completion in FY2017), and was silent on a doubling period in his FY2012 budget. The FY2013 budget request reiterated President Obama's intention to double funding for the targeted accounts from their FY2006 levels but did not specify the length of time over which the doubling was to take place. President Obama's FY2014 budget

[1] This report refers to these agencies and accounts collectively as the "targeted accounts" and the effort to double their aggregate funding as "the doubling effort." In 2006, the targeted accounts funded 55.8% of federal PS&E basic research, but only 4.7% of federal PS&E applied research.

[2] Any positive rate of growth will double funding over some period of time. Annual growth of 10%, for example, will double funding over approximately seven years; a 2% annual growth rate would result in doubling in 35 years.

[3] This report uses the aggregate FY2006 funding level as the baseline for assessing growth rates and doubling periods.

> expressed a commitment to increasing funding for the targeted accounts, but did not commit to doubling. The President's FY2015 and FY2016 budgets contained no explicit statement of commitment to increasing funding for the targeted accounts. For FY2016, President Obama is requesting $13.877 billion in aggregate funding for the targeted accounts, an increase of $752 million (5.7%) above the estimated FY2015 aggregate funding level of $13.125 billion. If enacted, this funding level would set a doubling pace, relative to the FY2006 level, of about 20 years.

Appropriations have not kept pace with the doubling goals set by President Bush, those initially embraced by President Obama, or those authorized by Congress under the America COMPETES Act and America COMPETES Reauthorization Act of 2010. Some Members of Congress continue to advocate for a doubling approach for specific agencies and for particular disciplines. However other advocates for increased funding have moved away from using the "doubling" framework as the appropriate goal for such increases, asserting instead that "sustained and predictable" federal funding is a better framework. This latter approach is specifically articulated in the America COMPETES Reauthorization Act of 2015 (H.R. 1806):

> It is the sense of Congress that sustained, predictable Federal funding is essential to United States leadership in science and technology.

This report provides information and analysis on the origins of the doubling effort; selected acts of Congress, other events, and reports; authorizations and appropriations; the effects of the doubling effort on the funding level and character of federal research funding for the physical sciences and engineering disciplines; and related policy issues.

Background

The adequacy of federal research funding has been an ongoing concern of federal policymakers for decades. For example, during his term in office, President George H. W. Bush sought to double funding for NSF;[4] NSF funding increased approximately 42.2% from FY1989 to FY1993.[5] Throughout the 1990s and into the 2000s a wide range of policymakers, companies, scientific and engineering organizations, research universities, and advocacy groups expressed concerns about whether there was sufficient federal funding for physical sciences and engineering (PS&E) research.[6] Some proponents for increases in federal PS&E research funding asserted that federal funding for these disciplines had stagnated or declined in constant dollars and as a share of U.S. gross domestic product for an extended period of time.[7] As a result, advocates argued, U.S. technological leadership and industrial competitiveness were at risk, with significant implications for long-term U.S. economic growth and job creation. In addition, some advocates asserted a strong and beneficial linkage between the magnitude of federal research and development (R&D) investments and the number of students earning doctorate degrees in science and engineering fields.[8] Others countered that such a benefit was not relevant as there were an

[4] Michael Boskin, "Industrial Policy Returns from the Grave," *Project Syndicate*, November 23, 2009.

[5] CRS analysis of historical budget authority data from Office of Management and Budget's Public Budget Database published with the President's FY2016 budget request.

[6] Some advocates also called for similar increases in mathematics and computer science research.

[7] See for example **Figure 5**.

[8] Robert D. Atkinson and Merrilea Mayo, *Refueling the U.S. Innovation Economy: Fresh Approaches to Science, Technology, Engineering, and Mathematics (STEM) Education*, Information Technology and Innovation Foundation, p. 128, http://www.intelligentcommunity.org/clientuploads/PDFs/2010-refueling-innovation-economy.pdf.

adequate number of scientists and engineers to meet the demand for their skills, and that the existing science and engineering education pipeline was sufficient to meet anticipated needs.

Those concerned about insufficient funding for PS&E research began advocating for an effort by Congress and the President to double research funding in these disciplines. Some argued for even larger increases or for including additional fields, such as mathematics, computer science, and defense basic research.[9] The proposals to double PS&E funding were similar to the effort that approximately doubled federal funding for the National Institutes of Health (NIH) between FY1998 and FY2003.[10] The NIH doubling was also cited by PS&E doubling advocates as a cause of concern in that it shifted the composition of the federal R&D budget, weighting it more heavily toward the life sciences than in the past. Those advocating for an increase in PS&E were careful not to suggest that the NIH budget be reduced to rebalance the federal portfolio, arguing that additional funds be devoted to PS&E instead. Further, in making the case for increased PS&E funding, some argued that, aside from its other value, the life sciences are dependent on PS&E research. For example, former NIH director Harold Varmus, arguing in support of substantial increases for NSF and the DOE Office of Science, posited that PS&E advances were instrumental to advances in the life sciences:

> Medical advances may seem like wizardry. But pull back the curtain, and sitting at the lever is a high-energy physicist, a combinational chemist or an engineer…. Scientists can wage an effective war on disease only if we—as a nation and as a scientific community—harness the energies of many disciplines, not just biology and medicine. The allies must include mathematicians, physicists, engineers and computer and behavioral scientists.[11]

Selected Milestones in the Doubling Effort

Concerns about underfunding of PS&E research and a growing imbalance in the federal R&D portfolio grew through the 1990s and early 2000s. In 2002, Congress enacted the National Science Foundation Authorization Act of 2002 (P.L. 107-368), setting authorization levels for NSF at a pace that would have more than doubled the agency's funding over five years (FY2002-FY2007). Actual appropriations did not keep pace with this act's authorization levels.[12] The focus on doubling funding for PS&E became more pronounced in the mid-2000s. The following section reviews selected milestones in the doubling effort beginning in 2005.

National Summit on Competitiveness

Advocates' arguments for increased federal PS&E funding resonated with some leaders in Congress. In April 2005, Congress included a provision in an emergency supplemental appropriations bill (P.L. 109-13, §6059) that directed the U.S. Department of Commerce to convene a meeting of U.S. manufacturers to discuss what could be done to foster U.S. competitiveness in the global economy. In December 2005, the Commerce Department hosted the National Summit on Competitiveness with four Cabinet Secretaries and more than 50 company

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[9] For example, in a letter dated May 3, 2005, Rep. Frank R. Wolf, chairman of the House Committee on Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies, asked President Bush to make a commitment to tripling federal basic research and development over a 10-year time span.

[10] Funding for NIH grew from $13.7 billion in FY1998 to $27.1 billion in FY2003. For additional information on the NIH doubling see CRS Report R41705, *The National Institutes of Health (NIH): Background and Congressional Issues*, by (name redacted) .

[11] Harold Varmus, "Squeeze On Science," *The Washington Post*, October 4, 2000, p. A33.

[12] NSF's FY2007 appropriation of $5,884.4 million was approximately 23% above its FY2002 funding level.

chief executive officers, university presidents, and agency directors in attendance.[13] A summit statement, purportedly representing a consensus of the participants, made increased basic research funding for PS&E its first recommendation:

> Revitalize Fundamental Research. Increase the federal investment in long-term basic research by 10 percent a year over the next seven years with focused attention to the physical sciences, engineering, and mathematics.[14]

The Gathering Storm Report

On May 27, 2005, Senators Lamar Alexander and Jeff Bingaman wrote a letter to the National Academies requesting a response to the following questions:

> What are the top 10 actions, in priority order, that federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century?[15]

Subsequently, Representatives Sherwood Boehlert and Bart Gordon, then the chairman and ranking Member of the House Committee on Science, sent a separate letter expanding on the request made in the earlier letter.

The National Academies responded to these letters with a report titled *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Released in October 2005,[16] the report offered 4 recommendations and 20 specific actions. The first proposed action was to double long-term basic research over seven years:

> The United States must ensure that an adequate portion of the federal research investment addresses long-term challenges across all fields, with the goal of creating new technologies. The federal government should increase our investment in long-term basic research—ideally through reallocation of existing funds, but if necessary via new funds—by 10% annually over the next 7 years. It should place special emphasis on research in the physical sciences, engineering, mathematics, and information sciences and basic research conducted by the Department of Defense (DOD).[17]

The report puts forward several rationales for this recommendation, including a decline in the federal government's share of U.S. R&D; a decline in federal R&D funding as a share of U.S. gross domestic product (GDP); a shift in the composition of the federal research budget towards the life sciences; and relatively flat funding, in constant dollars, for PS&E research for 15 years. The report asserts that a balanced federal R&D portfolio is "critical to U.S. prosperity," and that private industry underinvests in basic research for a variety of reasons, including its high risk and

[13] Computing Research Association, *Lots of News Re: The Case for R&D and U.S. Competitiveness*, December 5, 2005, http://www.cra.org/govaffairs/blog/2005/12/lots-of-news-re-the-case-for-rd-and-u-s-competitiveness/.

[14] National Summit on Competitiveness statement, December 6, 2005, http://www.nist.gov/mep/upload/competitiveness-innovation-2.pdf.

[15] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, and Committee on Science, Engineering, and Public Policy, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, National Academies Press, 2007, http://www.nap.edu/catalog/11463.html.

[16] A prepublication version of the *Gathering Storm* was released in October 2005; the final version (described in footnote 15) was published in 2007.

[17] Ibid. While recommending that the increase in funds for long-term basic research should come from reallocation of existing funds, the report includes a footnote stating, "The funds may come from anywhere in government, not just other research funds."

shareholder pressure for short-term returns. The *Gathering Storm* has been cited repeatedly by advocates in asserting a rationale and justification for the doubling effort.

American Competitiveness Initiative

In his 2006 State of the Union Address, President George W. Bush announced the American Competitiveness Initiative, an effort to address research and education issues to sustain U.S. leadership in science and technology:

> Tonight I announce the American Competitiveness Initiative to encourage innovation throughout our economy and to give our nation's children a firm grounding in math and science. First, I propose to double the federal commitment to the most critical basic research programs in the physical sciences over the next 10 years. This funding will support the work of America's most creative minds as they explore promising areas such as nanotechnology, supercomputing, and alternative energy sources.

Shortly thereafter, the Administration released a publication, entitled *American Competitiveness Initiative: Leading the World in Innovation,*[18] that provided detailed information about the proposal. Among other things, the report committed the Administration to doubling funding over 10 years for "innovation-enabling physical science and engineering research" at three agencies—NSF, the DOE Office of Science, and NIST,[19] which the report described as "key Federal agencies that support basic research programs in the physical sciences and engineering."

The ACI called for a doubling over 10 years, in contrast to the 7-year doubling recommended in the *Gathering Storm* report and the National Summit on Competitiveness statement. In addition, the ACI targeted agencies with strong foci on PS&E research to achieve its purpose of increasing federal PS&E research funding. While the ACI sought to make "similarly high-leverage programs a significant priority, such as basic and applied research at the Department of Defense," it characterized these efforts as being "in addition to" the doubling effort.

The ACI did not include yearly agency appropriations targets. Instead, it established FY2006 as a base year; noted the funding levels proposed in the President's budget for FY2007; and set illustrative agency targets for FY2016, the year in which doubling was to be completed. The ACI did not commit to doubling the individual budgets of the targeted accounts, but rather aggregate funding for the accounts. Subsequently, President Bush proposed funding for the targeted accounts in support of the ACI as part of his FY2008 and FY2009 budgets; these requests were consistent with a 10-year doubling pace (as measured by compound annual growth rate (CAGR)).[20] While the ACI ended with the completion of President Bush's second term in January 2009, President Obama continued the doubling effort as part of *The President's Plan for Science and Innovation*,[21] and set a 10-year doubling goal in his FY2010 budget (anticipating completion

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[18] Domestic Policy Council and Office of Science and Technology Policy, Executive Office of the President, *American Competitiveness Initiative: Leading the World in Innovation*, Washington, DC, February 2006, http://www.nsf.gov/attachments/108276/public/ACI.pdf.

[19] The report identified "NIST Core" as the NIST functions targeted for doubling, and defined the NIST Core as the Scientific and Technical Research and Services (STRS) and Construction of Research Facilities (CRF) accounts.

[20] CAGR is a calculated growth rate which, if applied year after year to a beginning amount, reaches a specified final amount (in the case of the doubling effort, an amount twice as large as the beginning amount). The compound annual growth rate required to double the aggregate funding of the targeted accounts over a 10-year period is approximately 7.2%.

[21] Office of Science and Technology Policy, Executive Office of the President, *The President's Plan for Science and Innovation*, Washington, DC, May 7, 2009, http://www.whitehouse.gov/files/documents/ostp/budget/doubling.pdf.

in FY2016). However, in subsequent budgets, President Obama first extended the doubling period then omitted the doubling language.

America COMPETES Act[22]

In 2007, Congress provided a legislative foundation for the doubling effort. Several bills were introduced in the 110th Congress that sought to address federal funding for PS&E research and other issues related to U.S. scientific and technological leadership and competitiveness. Selected provisions of these bills were later merged into a single bill, the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act, known more broadly as the America COMPETES Act (H.R. 2272).[23] This bill was passed with broad bipartisan support in both the House and the Senate. President Bush signed the act into law on August 9, 2007.

Among its provisions, the America COMPETES Act authorized appropriations for the targeted accounts identified in President Bush's ACI.[24] (The Energy Policy Act of 2005 (P.L. 109-58) previously set authorization levels for the DOE Office of Science for FY2008 and FY2009.) While the act did not explicitly state an intention to double aggregate funding for these accounts, it set authorization levels for the targeted accounts for FY2008-FY2010 that established a CAGR that, if continued through FY2013, would have resulted in doubling over seven years.[25] (See **Table 1**.) Appropriations generally did not reach the levels authorized by this act.

Table 1. Authorization Levels for Targeted Accounts, FY2008-FY2010

(in millions of current dollars)

Agency	FY2006 Actual	FY2008 Authorization	FY2009 Authorizatio n	FY2010 Authorization
National Science Foundation	$5,645.8	$6,600.0	$7,326.0	$8,132.0
DOE Office of Science	3,632.0	4,586.0	5,200.0	5,814.0
National Institute of Standards and Technology[a]	568.4	653.0	628.3	634.5

[22] For more information on the America COMPETES Act, see CRS Report R43880, *The America COMPETES Acts: An Overview*, by (name redacted) , and CRS Report R42779, *America COMPETES Acts: FY2008 to FY2013 Funding Tables*, by (name redacted) .

[23] The America COMPETES Act incorporated, in part, several House bills that had been introduced, and in some cases passed, earlier in the 110th Congress, including the 10,000 Teachers, 10 Million Minds Science and Math Scholarship Act (H.R. 362); the Sowing the Seeds Through Science and Engineering Research Act (H.R. 363); an act to amend the High-Performance Computing Act of 1991 (H.R. 1068); the National Science Foundation Authorization Act of 2007 (H.R. 1867); the Technology Innovation and Manufacturing Stimulation Act of 2007 (H.R. 1868); and an act to provide for the establishment of the Advanced Research Projects Agency-Energy (H.R. 364). Each of these bills was reported by the House Committee on Science and Technology. On the Senate side in the 110th Congress, S. 761 was similar to the National Competitiveness Investment Act (S. 3936, 109th Congress) introduced at the end of the 109th Congress.

[24] The America COMPETES Act is an authorization act. Funds authorized under this act required separate appropriations acts to provide the funding necessary to realize the doubling.

[25] The periods for doubling for both the America COMPETES Act and the Reauthorization Act are calculated by determining their CAGR and using it to determine how long it would take to double at that growth rate. The CAGR calculated for the America COMPETES Act, measured from FY2006 to FY2010, is 10.3%, which equates to a doubling period of approximately seven years. The CAGR calculated for the Reauthorization Act, measured from FY2006 to FY2013, is 6.3%, which equates to a doubling period of approximately 11 years.

Agency	FY2006 Actual	FY2008 Authorization	FY2009 Authorizatio n	FY2010 Authorization
Total	**9,846.2**	**11,839.0**	**13,154.3**	**14,580.5**

Sources: FY2006 actual from agency FY2008 budget justifications. Authorizations from P.L. 110-69, except DOE FY2008 and FY2009 from the Energy Policy Act of 2005 (P.L. 109-58).

a. Includes only the NIST STRS and CRF accounts.

America COMPETES Reauthorization Act of 2010

In December 2010, Congress passed the America COMPETES Reauthorization Act of 2010 (P.L. 111-358, hereinafter referred to as the "2010 COMPETES Act"). The act, among other things, established authorization levels for the targeted accounts for FY2011 through FY2013.

Just as the 2007 America COMPETES Act did not explicitly establish a doubling effort, neither did the 2010 COMPETES Act. The 2010 COMPETES Act set authorization levels for the targeted accounts for FY2011-FY2013 that established a CAGR that, if continued past FY2013, would result in doubling over a period of somewhat more than 11 years.

Table 2. Authorization Levels for Targeted Accounts, FY2011-FY2013

(in millions of current dollars)

Agency	FY2011 Authorization	FY2012 Authorization	FY2013 Authorization
National Science Foundation	$7,424.0	$7,800.0	$8,300.0
DOE Office of Science	5,247.0	5,614.0	6,007.0
National Institute of Standards and Technology[a]	709.3	746.0	798.0
Total	13,380.3	14,160.0	15,105.0

Sources: America COMPETES Reauthorization Act of 2010 (P.L. 111-358).

a. Includes only the NIST STRS and CRF accounts.

Progress Toward the Doubling Targets

This section provides an analysis of progress toward the goal of doubling aggregate funding for the targeted accounts from their aggregate FY2006 level. In this analysis, there are two important points to note:

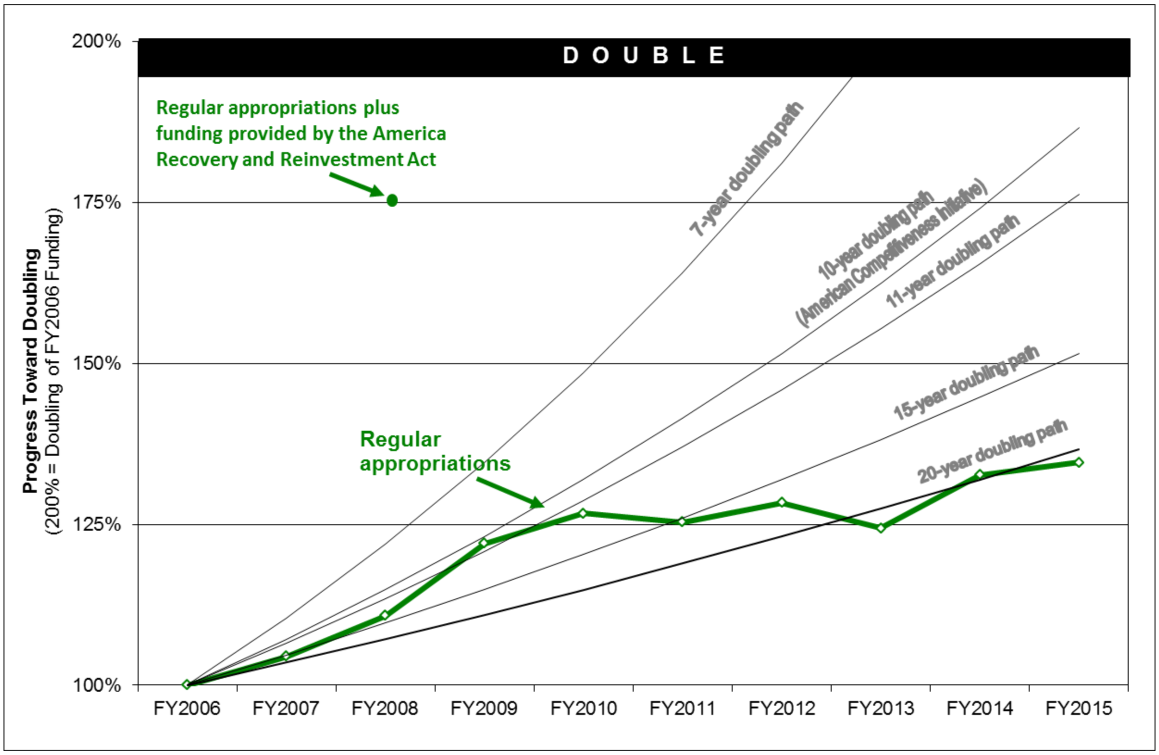
First, the American Recovery and Reinvestment Act (ARRA, P.L. 111-5), a broad supplemental appropriations act passed in FY2009, included substantial funds for each of the targeted accounts. Since ARRA was a supplemental appropriation and not part of the base appropriations of the agencies, these funds are not included in this report's analysis of the doubling effort, except inasmuch as they are represented in **Figure 1**.

Second, there is no clear answer to the question of how successful the doubling effort has been because policymakers have set, explicitly and implicitly, different periods for doubling. And, as importantly, some policymakers are currently seeking to address the perceived need for increased funding for PS&E using a framework that supports sustained and predictable increases rather than using a doubling goal.

Actual Appropriations[26]

From FY2006 to FY2015, aggregate funding for the targeted accounts grew by 33.3%, consistent with a doubling period of more than 21 years, which is substantially beyond the timeframes of the ACI, the America COMPETES Act, the 2010 COMPETES Act, and those explicitly set by President Obama. **Figure 1** illustrates aggregate regular appropriations (shown in green) for the targeted accounts from FY2006 through FY2015. Seven-year, 10-year, 11-year, 15-year, and 20-year doubling paths are included in the figure for reference.

Figure 1. Appropriations for Targeted Accounts, FY2006-FY2015, as a Percentage of FY2006 Funding



Sources: Agency budget justifications, FY2008-FY2016.

Another way of measuring the success of the doubling effort is to look at how the pace of growth (as measured by CAGR) for the targeted accounts during the doubling effort compares to past levels of funding growth for these accounts. **Table 3** provides the CAGR for aggregate budget authority of the targeted accounts for selected periods, in both current and constant dollars, including the three 10-year periods immediately preceding the doubling effort.[27] The conversion to constant dollars removes the effects of inflation so that the numbers are more comparable across time periods.

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[26] For additional information of COMPETES-related authorization and appropriations, see CRS Report R42779, *America COMPETES Acts: FY2008 to FY2013 Funding Tables*, by (name redacted) .

[27] The Office of Management and Budget uses the GDP chained price index as a deflator to calculate constant dollar R&D funding. These deflators are available in Table 10.1, *Budget of the United States Government, Fiscal Year 2013.*

Table 3. Compound Annual Growth Rates for Targeted Accounts, Selected Periods

Period	CAGR, Current Dollars	CAGR, Constant Dollars
FY1976 - FY1986 (actual)	7.3%	1.1%
FY1986 - FY1996 (actual)	7.1%	4.2%
FY1996 - FY2006 (actual)	8.4%	6.1%
FY2006 (actual) - FY2015 (enacted)	3.4%	1.7%

Source: CRS analysis of budget authority data from agency budget justifications, FY2008-FY2016. Constant dollars calculated using the GDP (chained) price index for FY2015 and FY2016 in Table 10.1, Gross Domestic Product and Deflators Used in the Historical Tables: 1940–2020, Budget of the United States Government, Fiscal Year 2016, http://www.whitehouse.gov/sites/default/files/omb/budget/fy2016/assets/hist10z1.xls.

Notably, the 1.7% CAGR (constant dollars) in actual appropriations for the period in which the doubling effort has taken place (FY2006-FY2015) is less than one-third of the 6.1% CAGR for the 10-year period immediately prior to the start of the doubling effort (FY1996-FY2006) and less than half the FY1986-FY1996 period (4.2% CAGR). Viewed in current dollars, the CAGR during the doubling period is less than each of the three preceding 10-year periods. If funding increases were deemed inadequate during these preceding periods, then some may conclude that a lower or similar rate of increase will not address the underlying reasons for pursuing a doubling of the targeted accounts.

Presidential Doubling Periods and Budget Requests Versus Actual Appropriations

President Bush made three budget requests (FY2007-FY2009) in support of the American Competitiveness Initiative (ACI). The requested increases in aggregate funding for the targeted accounts for these years were consistent with a pace that would have doubled funding in approximately 10 years, the period set by President Bush in the ACI.[28] President Obama has made seven budget requests (FY2010-FY2016). **Table 4** shows the request level, CAGR, and doubling pace for each of the requests.

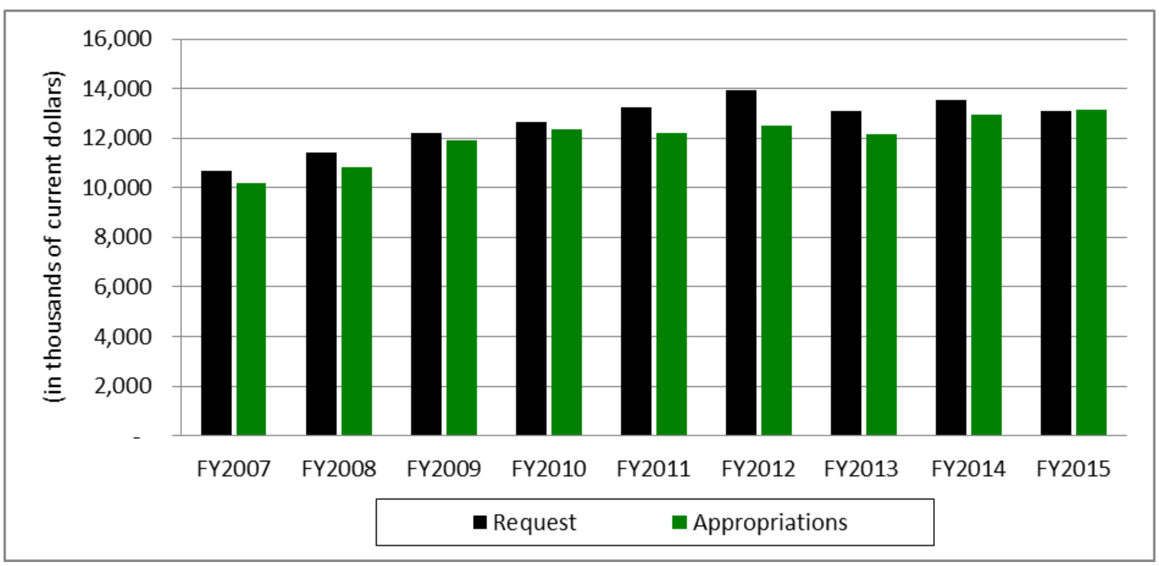
[28] The CAGRs for aggregate funding for the targeted accounts under President Bush's requests were 8.2% for FY2007, 7.7% for FY2008, and 7.4% for FY2010, as measured from the from 2006 baseline.

Table 4. Requested Funding for Targeted Accounts, with Associated Compound Annual Growth Rate and Doubling Pace, FY2006-FY2016

Fiscal Year	Proposed Doubling Period	Requested Funding	CAGR (from FY2006 base)	Doubling Pace Represented by Requested Funding (from FY2006 base)
President George W. Bush				
FY2007	10 years	$10,656,9	8.2%	8.8 years
FY2008	10 years	11,421.3	7.7%	9.3 years
FY2009	10 years	12,210.1	7.4%	9.7 years
President Barack Obama				
FY2010	10 years	12,638.2	6.4%	11.1 years
FY2011	11 years	13,255.1	6.1%	11.7 years
FY2012	Doubling goal stated; no timeframe specified	13,946.6	6.0%	11.9 years
FY2013	Doubling goal stated; no timeframe specified	13,073.2	4.1%	17.1 years
FY2014	Goal of increasing funding for targeted accounts; no commitment to doubling	13,532.3	4.1%	17.4 years
FY2015	No commitment to doubling	13,105.2	3.2%	21.8 years
FY2016	No commitment to doubling	13,877.3	3.5%	20.2 years

From FY2007 to FY2014, Congress appropriated less for the targeted accounts (in aggregate) than President Bush and President Obama requested; for FY2015, Congress appropriated slightly more than the requested level. (See **Figure 2**.)

Figure 2. Presidential Requests and Appropriations for Targeted Accounts, Annual Aggregates, FY2007-FY2015



Sources: Agency budget justifications, FY2008-FY2016.

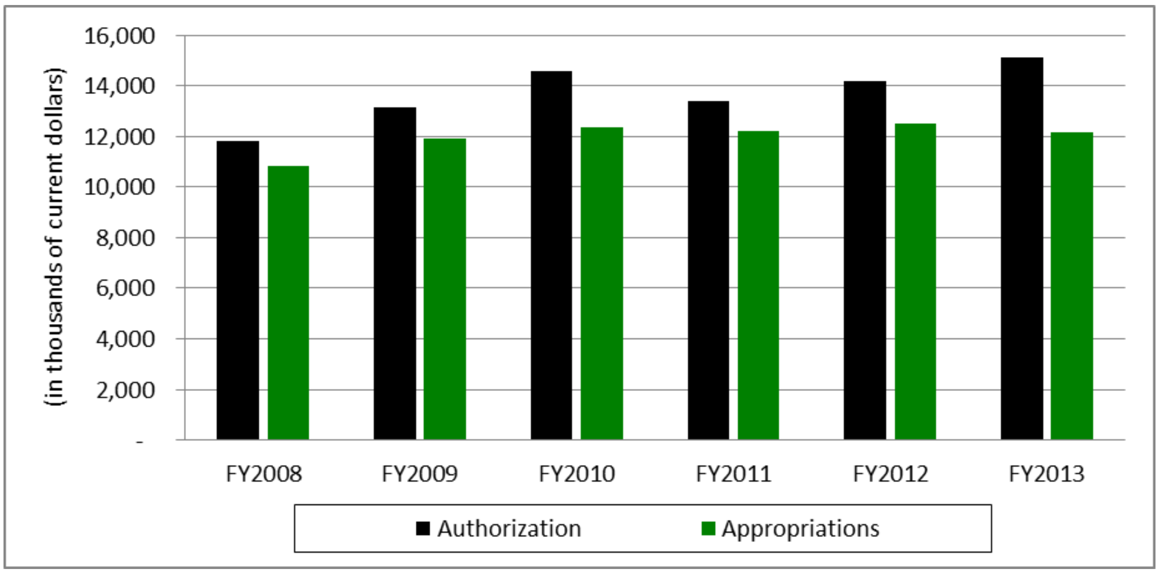
Notes: Appropriations figures for FY2006-FY2013 are actual; figures for FY2014 are actual, enacted, or current funding levels as reported by each agency in its FY2016 congressional budget justifications. FY2015 are enacted.

Congressional Doubling Periods Versus Actual Appropriations

In 2007, the 110th Congress authorized funding for the targeted accounts for FY2008-FY2010 in the America COMPETES Act. The act, among other things, authorized aggregate funding for these accounts for FY2010 at a level representing a 10.3% CAGR over FY2006 actual funding, a pace consistent with doubling in approximately seven years. Congress, however, subsequently appropriated less funding for the targeted accounts than it had authorized (see **Figure 3**); as a result, actual FY2010 funding represented a 6.4% CAGR over FY2006 funding, consistent with an 11-year doubling path.

The America COMPETES Reauthorization Act of 2010, among other things, established authorization levels for the targeted accounts for FY2011-FY2013. Aggregate authorizations for these accounts for FY2013 represented a 6.4% CAGR over FY2006 actual funding, a pace consistent with doubling in somewhat more than 11 years. As before, however, Congress subsequently appropriated less than it had authorized (see **Figure 3**). Actual FY2013 funding represented a CAGR of 3.2% over FY2006, corresponding to a 22-year doubling period.

Figure 3. Authorizations and Appropriations for Targeted Accounts, Annual Aggregates, FY2008-FY2013

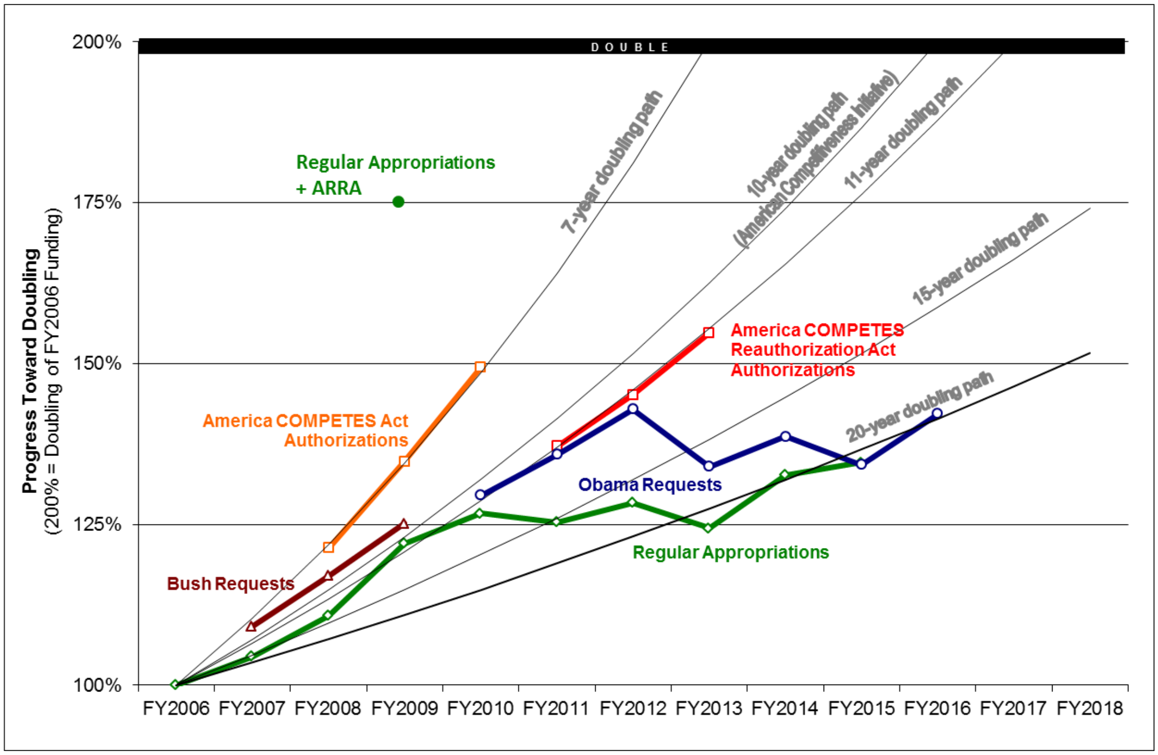


Sources: Authorizations: FY2008-2010, P.L. 110-69; FY2011-2013, P.L. 111-358. Appropriations: agency budget justifications, FY2011-FY2015.

An Integrated Perspective

Figure 4 provides an integrated view of how the ACI, presidential budget requests, authorizations, and appropriations compare to various doubling periods as a percentage of the FY2006 aggregate appropriations for the targeted accounts. On this chart, appropriations would need to reach 200% (top bar, in black) to achieve a doubling of the targeted accounts from their FY2006 level.

Figure 4. Doubling of Research Funding for Targeted Accounts: Appropriations and Authorizations versus Selected Rates



Source: Prepared by CRS based on data from the Office of Management and Budget and agency budget justifications for FY2008 to FY2016 and agency authorization levels from the America COMPETES Act (P.L. 110-69) and the America COMPETES Reauthorization Act of 2010 (P.L. 111-358).

Policy Issues

Attempts to double funding for the targeted accounts and thereby to increase funding for PS&E research have raised a number of challenging policy issues:

- How has the doubling effort affected federal PS&E research funding?
- Should the federal government double funding for PS&E research?
- Would increased federal investment in PS&E research produce jobs and economic growth for the United States?
- How might the doubling effort affect the number of students pursuing PS&E degrees?

How Has the Doubling Effort Affected Federal PS&E Research Funding?

How effective has the doubling effort been in increasing federal funding for PS&E research? The NSF's *Survey of Federal Funds for Research and Development* is the only comprehensive data source for addressing this question. This annual survey of federal R&D agencies provides data on, among other things, federal obligations for basic and applied research by detailed field of science and engineering, including physical sciences and engineering.[29]

The following discussion includes analysis of federal PS&E research obligations for the FY2006-FY2013 period. This analysis first examines changes in obligations for PS&E in current (or nominal) dollars,[30] by looking at changes in basic research, applied research, and research at the doubling agencies,[31] then for all federal agencies. The second part of the analysis examines the changes in constant dollars to provide an understanding of how the real purchasing power of PS&E funding has changed over this period.

Changes in Current Dollar Obligations

Basic Research

A primary goal of the doubling effort, as articulated in the ACI and in congressional debate during consideration of the America COMPETES Act, is to increase basic research funding in the physical sciences and engineering.

From FY2006 to FY2013, current dollar obligations for PS&E basic research at the doubling agencies increased by 28.5%. This increase computes to a 3.6% CAGR, a doubling pace of more than 19 years. During the same period, total federal obligations (at all agencies) for PS&E basic

[29] This report's analysis of changes in federal obligations for PS&E research during the doubling period (post-FY2006) is limited by two factors. First, collection and publication of data of how federal research funds are spent by scientific and engineering fields generally lags appropriations by a year or more since the reporting is based on obligations (how the appropriations were committed to be spent). Second, while the most recent NSF *Survey of Federal Funds for Research and Development* provides data through FY2015, NSF characterizes the data for FY2014 as preliminary (i.e., subject to change) and the FY2015 data as being based on estimates using the President's FY2015 budget request not actual appropriations or actual obligations. For this reason, CRS has chosen to use only data through FY2013.

[30] The terms "nominal" and "current" are used to describe funding levels that have not been adjusted for inflation.

[31] In this context, "doubling agencies" refers to NIST, NSF, and the DOE Office of Science, whose accounts (some or all) were targeted for doubling.

research increased by 33.3% in current dollars. This increase computes to a 4.2% CAGR, a faster pace than in the preceding decade (2.8%, FY1996-FY2006). At a 4.2% CAGR, it would take almost 17 years for total federal PS&E obligations to double. (See **Table 5**.)

Notably, the agencies that were not targeted as a part of the doubling effort experienced a faster growth rate in their PS&E basic research obligations (4.9% CAGR) than did the doubling agencies. The doubling agencies provided a little less than half ($935.8 million, 47.8%) of the total increase in PS&E basic research obligations ($1.960 billion) between FY2006 and FY2013, even though they accounted for 55.8% of total PS&E basic research funding in FY2006. (Federal PS&E basic research obligations for the targeted agencies and selected other agencies for FY2006 and FY2013 are provided in **Table A-2**.)

It is likely that increases in total federal obligations for PS&E research were bolstered during this period by the National Aeronautics and Space Administration's (NASA's) reclassification of its International Space Station (ISS) obligations in FY2012; prior to FY2012, NASA reported such obligations as R&D plant, while obligations for FY2012 and subsequent years have been reported as research.[32] Thus, since NASA did not report such obligations as research in FY2006 (the base year for this analysis), but did for FY2013 (the final year of this analysis), the reclassification of ISS obligations may have resulted in additional growth in reported PS&E obligations even though much of NASA's work on the ISS has not substantially changed character. NASA obligations for PS&E basic research accounted for 30.1% of the overall increase in federal PS&E obligations between FY2006 and FY2013.

Table 5. Compound Annual Growth Rates for Total Federal Basic Research Obligations in Physical Sciences, Engineering, and PS&E Combined for Selected Periods

(based on analysis of current dollars)

Period	Physical Sciences	Engineering	PS&E
FY1996-FY2006	2.1%	3.9%	2.8%
FY2006-FY2013	3.4%	5.4%	4.2%

Source: CRS analysis of data from National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 2007-09*, NSF 10-305, May 2010; National Science Foundation, *Federal Research and Development and R&D Plant Funding Drop by 9% in FY 2013*, NSF 15-322, May 14, 2015; and unpublished tables provided to CRS by NSF by email on May 14, 2015.

Applied Research

Though applied research is not the focus of the doubling effort, it is noteworthy that the growth rate for total federal obligations for PS&E applied research (2.0% CAGR) during the FY2006-FY2013 period was less than half that of the previous decade (4.7% CAGR, see **Table 6**).[33]

[32] NASA began reporting ISS obligations as research rather than R&D plant beginning in FY2012. According to NSF, "The new reporting methods NASA is using resulted in a $2 billion dollar increase in what NASA reports as R&D." [Email communication between CRS and NSF National Center for Science and Engineering Statistics staff, May 20, 2015.] A portion of NASA ISS funding is likely included in PS&E research data for FY2013 that was not included in the FY2006 data.

[33] If NASA's ISS obligations for applied research were removed from the FY2013 data (or, alternatively, added to the FY2006 data) to provide greater comparability (see earlier discussion and footnote 32), the CAGR for FY2006-FY2013 might be reduced further. The tables provided by NSF to CRS do not parse the data at a level that allows NASA's ISS obligations to be removed from the FY2013 data.

In addition, while total federal PS&E basic research grew at 4.2% CAGR during the FY2006-FY2013 period, total federal PS&E applied research grew at a comparatively slower 2.0% CAGR. Growth in PS&E applied research obligations for the doubling agencies was 4.6% CAGR. However the doubling agencies account for less than 6% of total federal PS&E applied research obligations and thus their growth has a small impact on the overall growth rate. (Federal PS&E applied research obligations for the targeted agencies and selected other agencies for FY2006 and FY2013 are provided in **Table A-3**.)

Table 6. Compound Annual Growth Rates for Total Federal Applied Research Obligations in Physical Sciences, Engineering, and PS&E Combined for Selected Periods

(based on analysis of current dollars)

Period	Physical Sciences	Engineering	PS&E
FY1996-FY2006	5.6%	4.5%	4.7%
FY2006-FY2013	0.1%	2.6%	2.0%

Source: CRS analysis of data from National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 2007-09*, NSF 10-305, May 2010; National Science Foundation, *Federal Research and Development and R&D Plant Funding Drop by 9% in FY 2013*, NSF 15-322, May 14, 2015; and unpublished tables provided to CRS by NSF by email on May 14, 2015.

Research (Basic and Applied)

Analysis of combined basic research and applied research obligations provides another perspective on the overall changes in PS&E research during the doubling period. Total federal obligations for PS&E research (basic and applied) grew at 3.0% CAGR for the FY2006-FY2013 period, less than the 3.9% CAGR pace for the previous decade (FY1996-FY2006).[34] (See **Table 7**.)

From FY2006 to FY2013, the doubling agencies' PS&E research grew at a faster pace (3.8% CAGR) than did total federal PS&E research (3.0% CAGR). (Federal PS&E research (basic and applied) obligations for the targeted agencies and selected other agencies for FY2006 and FY2013 are provided in **Table A-4**.)

Table 7. Compound Annual Growth Rates for Total Federal Research (Basic and Applied) Obligations in Physical Sciences, Engineering, and PS&E Combined for Selected Periods

(based on analysis of current dollars)

Period	Physical Sciences	Engineering	PS&E
FY1996-FY2006	3.2%	4.3%	3.9%
FY2006-FY2013	2.3%	3.4%	3.0%

Source: CRS analysis of data from National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 2007-09*, NSF 10-305, May 2010; National Science Foundation, *Federal Research and Development and*

[34] The overall research (basic and applied) CAGR of 3.0% during the FY2006-FY2013 period may have also been bolstered by the FY2012 reclassification of NASA ISS obligations discussed in footnote 32. While the ISS obligations cannot be teased out of the total NASA figures, if NASA applied research is removed from the calculation of total federal PS&E applied research, the CAGR falls to 2.0%.

R&D Plant Funding Drop by 9% in FY 2013, NSF 15-322, May 14, 2015; and unpublished tables provided to CRS by NSF by email on May 14, 2015.

In summary:

- PS&E basic research obligations for the doubling agencies grew at a slower pace (3.6% CAGR) than the pace for all other agencies combined (4.9% CAGR) from FY2006 to FY2013, and contributed less than half of the total increase in federal PS&E basic research obligations.
- Total federal obligations for PS&E basic research grew faster between FY2006 and FY2013 (4.2% CAGR) than in the prior decade (2.8% CAGR). However, total federal obligations for PS&E applied research grew at a slower pace (2.0% CAGR) between FY2006 and FY2013 period than in the prior decade (4.7% CAGR), and slower than the pace of growth for total (basic and applied) federal PS&E research (3.0% CAGR from FY2006-FY2013, 3.9% CAGR from FY1996-FY2006.)

This analysis is subject to the potential effect of NASA's reclassification of ISS obligations from R&D plant to research in FY2012. (See discussion in footnote 32.)

Constant Dollar Analysis: How Has the Real Purchasing Power of Federal PS&E Obligations Changed During the Doubling Effort?[35]

The doubling effort has focused on doubling nominal (non-inflation adjusted) funding for the targeted accounts. However, the real purchasing power of funding is affected by inflation. An analysis of how PS&E research obligations have changed when adjusted for inflation may provide a perspective on how real purchasing power has changed.

Basic research. In constant dollars, total federal obligations for PS&E basic research grew at 2.4% CAGR during the FY2006-FY2013 period, faster than PS&E basic research obligations of the doubling agencies which grew at 1.9% CAGR.

Applied research. In constant dollars, total federal obligations for PS&E applied research grew at 0.3% CAGR during the FY2006-FY2013 period, a pace lifted somewhat by faster growth (2.8% CAGR) in the PS&E applied research obligations of the doubling agencies.

Research (basic and applied). In constant dollars, PS&E research obligations of the doubling agencies grew at 2.0% CAGR during the FY2006-FY2013 period, faster than total federal obligations for PS&E research which grew at 1.2% CAGR.

This analysis is subject to the potential effect of NASA's reclassification of ISS obligations from R&D plant to research in FY2012. (See discussion in footnote 32.)

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[35] Constant dollar calculations for this report were made using the GDP chained price index published by the Office of Management and Budget in Table 10.1 of the Historical Tables of the *Budget of the United States Government, Fiscal Year 2016,* available at https://www.whitehouse.gov/sites/default/files/omb/budget/fy2016/assets/hist10z1.xls.

Should the Federal Government Double Funding for PS&E Research?

While the doubling effort has enjoyed widespread support among leaders in industry, academia, and government, others have raised concerns about whether the federal government should continue towards doubling PS&E research funding given the current national economic climate, federal budget deficit, and national debt.

Advocates for doubling assert that federal support for PS&E research is critical to U.S. economic and technological leadership, national security, and quality of life. They note that investments in PS&E since World War II have helped to foster the development of new products, services, and industries; deliver enormous economic benefits to the nation in terms of job creation, productivity, and economic growth; improve the quality of lives; secure the national defense; and propel the United States to global technological leadership. Not making similar investments now, say these advocates, would result in a failure to reinvest in and expand the knowledge base essential to deriving similar benefits in the future.

A second major thrust of doubling proponents is that years of underinvestment require a plan to quickly increase federal funding for research in these fields. They argue that inflation-adjusted federal funding for PS&E research was flat or negative for much of the 1990s and into the 2000s. While advocates have proposed a variety of periods for a doubling effort, their recommendations for a doubling timeframe generally fall in the 7- to 10-year range.

In general, opposition to doubling PS&E investments has centered on concerns about rapidly increasing federal expenditures in light of the federal deficit and national debt. As the U.S. economy has experienced a slowdown in growth and an increase in unemployment and underemployment, policymakers have focused increasingly on reducing federal discretionary spending—the source of most federal R&D funding—or at least on reducing its rate of growth.

In addition, even some doubling advocates (including OSTP Director John Holdren) have raised concerns about the potential harm of a "boom-bust" approach to federal PS&E research funding (i.e., rapid growth in federal R&D funding followed by much slower growth, flat funding, or even decline), arguing for a 10-year doubling period.[36] This concern stems, in part, from the experience of the biomedical community following a similar effort that doubled the National Institutes of Health's budget over five years. With the NIH doubling came a rapid expansion of the nation's biomedical research infrastructure (e.g., buildings, laboratories, equipment), as well as rapid growth in university faculty hiring, students pursuing biomedical degrees, and grant applications to NIH. After the doubling, however, the agency's budget fell each year in constant dollars from FY2004 to FY2009. Critics assert a variety of damages resulting from this boom-bust cycle, including interruptions and cancellations of promising research, declining share in the number of NIH grant proposals funded, decreased student interest in pursuing graduate studies, and reduced employment prospects for the large number of biomedical researchers with advanced degrees. According to then-NIH Director Elias Zerhouni, the damages have been particularly acute for early- and mid-career scientists seeking a first or second grant.[37] Such concerns have contributed,

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[36] Jennifer Couzin and Greg Miller, "NIH Budget: Boom and Bust," *Science*, vol. 316, no. 5823 (April 2007), pp. 356-361, at http://www.scienceonline.org/cgi/content/full/316/5823/356.

[37] Ibid. For additional information on NIH R&D funding issues, see CRS Report R41705, *The National Institutes of Health (NIH): Background and Congressional Issues*, by (name redacted) .

in part, to policymakers' views of how fast to pursue the PS&E doubling path. More recently, some policymakers and analysts have called for a new strategy of "sustained, predictable federal funding," as called for in the America COMPETES Reauthorization Act of 2015 (H.R. 1806).

Historically, there has been a broad consensus in support of a federal role in basic research. However, some analysts assert that federal R&D spending can displace private investment (i.e., that funding provided by the federal government will be used, in part, for R&D activities that the private sector would have funded in the absence of government spending). While some economists support this view, others believe that public support for R&D can be complementary to private R&D and even induce increases in private sector R&D spending.[38]

Economists generally agree that the private sector tends to underinvest in basic research due, in part, to its high risks and the long time required for its results to mature to the point where they produce economic benefit through the development of new products, services, or processes. These factors reduce the return on investment to the funder. In addition, the purpose of basic research is development of fundamental knowledge, often with no known commercial application at the time the research is conducted. Over time, the benefits derived from such new knowledge often extend beyond the investor (an effect known in economic terms as "spillover"). Since much of the benefits of basic research will likely be captured by those other than the investor, the private sector will underinvest in basic research, say many economists. This perspective provides a rationale for public funding of basic research and public sharing of the knowledge it generates. As articulated by Federal Reserve Chairman Ben Bernanke:

> The argument, which applies particularly strongly to basic or fundamental research, is that the full economic value of a scientific advance is unlikely to accrue to its discoverer, especially if the new knowledge can be replicated or disseminated at low cost. For example, James Watson and Francis Crick received a minute fraction of the economic benefits that have flowed from their discovery of the structure of DNA. If many people are able to exploit, or otherwise benefit from, research done by others, then the total or social return to research may be higher on average than the private return to those who bear the costs and risks of innovation. As a result, market forces will lead to underinvestment in R&D from society's perspective, providing a rationale for government intervention.[39]

While this argument suggests the value of some federal role in funding basic research, it does not address how much the federal government should invest. Some opponents may believe that the federal government already invests at or above the optimal level to address what the economists refer to as the "market failure" that results in private sector underinvestment.[40]

Some analysts argue that the failure to advance many promising early-stage products to large-scale commercial production—a challenge often referred to as the "valley of death"—is an indication that there is already more promising research available than the United States can efficiently use. By this argument, additional research might exacerbate the problem as promising new ideas compete for the same inadequate pool of resources needed for this phase of the

[38] For a broader discussion of the substitution/complementary character of public investments in R&D, see, for example, "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence," by Paul A. David, Bronwyn H. Hall, and Andrew A. Toole, Working Paper 7373, National Bureau of Economic Research, October 1999, available at http://www.nber.org/papers/w7373.

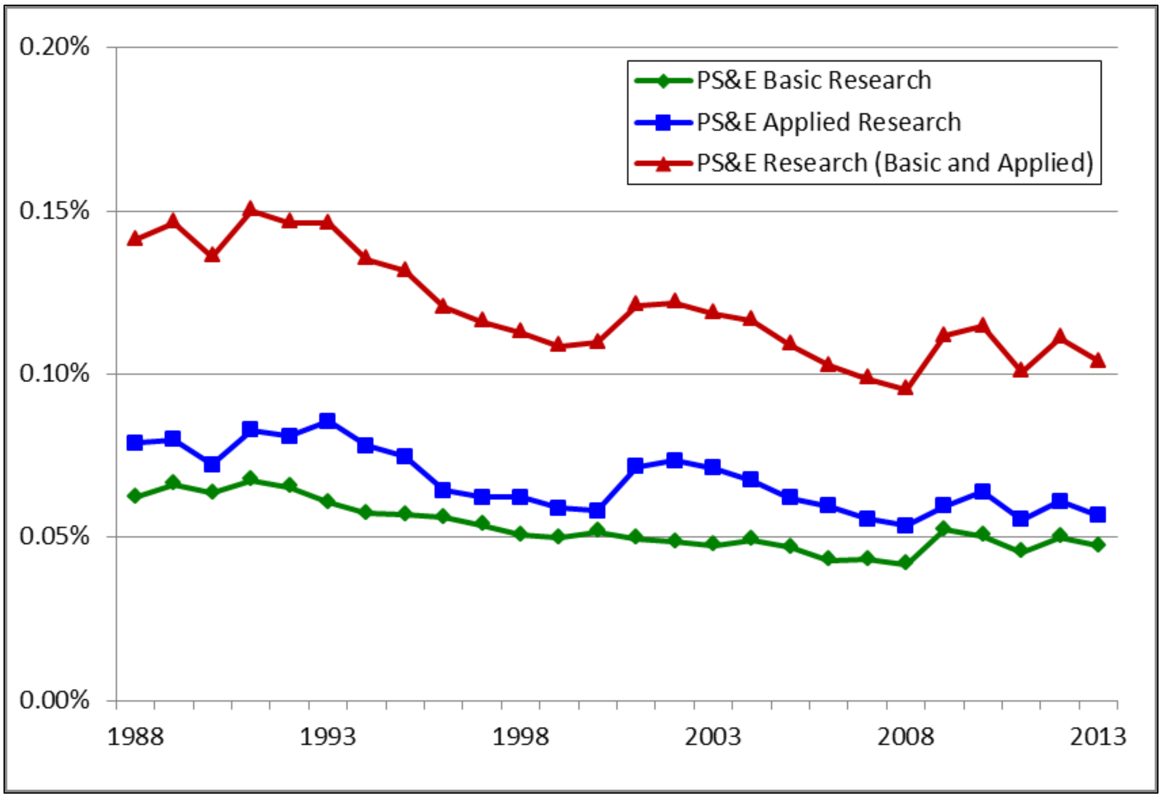
[39] Remarks of Ben S. Bernanke, Chairman, Board of Governors of the Federal Reserve Systems, entitled "Promoting Research and Development: The Government's Role," at the New Building Blocks for Jobs and Economic Growth conference, Washington, DC, May 16, 2011.

[40] A "market failure" is said to exist when conditions in a free market result in an inefficient allocation of resources.

innovation process. Additional research investments could be wasteful if new research remains unused or dormant for an extended period of time, or possibly even counterproductive if the research is capitalized upon by foreign competitors. Alternatively, additional policy efforts might be undertaken to overcome the challenges posed by the "valley of death," opening the commercialization pipeline, and rationalizing additional federal funding for basic research.

Some doubling advocates assert that federal PS&E research funding should keep pace with the size of the national economy, that is, that PS&E research funding as a share of gross domestic product (GDP) should be constant. Other analysts assert that the linkage between the rate of growth in federal PS&E research funding and the rate of growth of GDP is arbitrary. **Figure 5** shows federal PS&E basic, applied, and total (basic and applied) research obligations as a share of GDP. By this measure, basic, applied, and total PS&E research have all declined since FY1988 (the first year for which comparable data are available) although the decline appears to have leveled off between 2008 and 2013.

Figure 5. Federal PS&E Obligations for Research as a Percentage of GDP



Source: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development*; Office of Management and Budget, *Budget of the United States Government: Fiscal Year 2016*, Historical Tables, Table 10.1.

Would Increased Investment in PS&E Research Produce Jobs and Economic Growth for the United States?

A primary justification for the doubling effort has been that the research resulting from the additional federal investments in PS&E would increase U.S. competitiveness, jobs, and economic growth.[41] Many economists, scientists, and technologists argue that over the past 60-plus years the U.S. investment in research (mostly PS&E research in the earlier part of this period)[42] has produced substantial economic benefits.[43] In a 2000 National Bureau of Economic Research working paper, economists Michael Boskin and Lawrence Lau concluded that

> Technical progress accounts for more than 50 percent of the economic growth of the G-7 countries except Canada.[44]

Moreover, Boskin and Lau concluded that the absence of technical progress resulted in slower growth:

> The most important source of the growth slowdown since the mid-1970s, accounting for between one-third to one-half, is a decline in the rate of capital (both tangible and human)-augmenting technical progress.[45]

However, several factors might adversely affect the United States' ability to capture the desired economic benefits of such basic research investments. The factors include:

- Basic research may not translate into viable commercial applications.
- University start-ups may lack the resources needed to bring their innovations to market.
- Increased foreign R&D capability and industrial strength may reduce the U.S. ability to benefit preferentially from non-proprietary PS&E research.
- Basic research is generally available to all competitors and therefore may not provide U.S. firms with an advantage over foreign competitors.
- U.S.-based companies may conduct production and other work outside of the United States based on research results.
- U.S.-educated foreign students who return home to conduct research and create new businesses may take some of the benefits of university research with them.
- U.S. companies that conduct research and/or their intellectual property may be acquired by foreign competitors.

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[41] In addition to its potential economic benefits, PS&E research may contribute to other societal benefits such as better health care, improved quality of life, and reductions in pollution. Such benefits may accrue to the United States irrespective of which country PS&E research-enabled innovations originate or are produced. The arguments put forth in this section relate to the economic benefits of PS&E research as this was the primary focus of the COMPETES acts.

[42] In 1970, federal PS&E research accounted for 50.7% of total federal research, in 1971 the share fell below half (46.7%) and continued to fall, reaching 25.3% of total federal research in 2009. Since then, PS&E's share of federal research has increased somewhat (29.1% in 2013).

[43] See, for example: Robert M. Solow, "Perspectives on Growth Theory," *The Journal of Economic Perspectives*, vol. 8, no. 1 (Winter 1994), pp. 44-54; Michael J. Boskin and Lawrence J. Lau, "Post-War Economic Growth in the Group-of-Five Countries: A New Analysis," NBER Working Papers 3251, National Bureau of Economic Research, Inc., 1990; Edwin Mansfield, "Academic Research and Industrial Innovation," *Research Policy*, vol. 20 (February 1991), pp. 1-12.

[44] Boskin and Lau, "Generalized Solow-Neutral Technical Progress and Postwar Economic Growth," Working Paper 8023, *National Bureau of Economic Research Working Paper Series*.

[45] Ibid.

- U.S. and foreign government policies or other factors may affect whether and where research results are commercialized.

How Might the Doubling Effort Affect the Number of Students Pursuing PS&E Degrees?

In 2013, 23.2% of total federal physical science and engineering research (applied and basic) obligations and 38.5% of federal PS&E basic research obligations were performed by academia.[46] Federal investments in university-based research usually support, directly and indirectly, the education and training of new scientists and engineers at the graduate and post-graduate level. Increasing federal funding for university research would enable larger research grants and/or more research grants to academia. These additional funds enable a larger number of graduate and post-graduate students to participate in research, eventually increasing the number of trained research scientists and engineers in the U.S. workforce.

Many have argued that this effect is a positive one because they believe that there is a shortage of scientists and engineers in the United States, citing a variety of indicators and causes, including

- employers' assertions of difficulty in hiring students with the science and engineering skills they need,
- a decline in certain science and engineering degrees earned as a percentage of all undergraduate degrees earned,[47]
- new opportunities in emerging fields of science and engineering,
- policy challenges (e.g., societal, economic, national security) that might be addressed through advances in science and technology, and
- the large share of advanced science and engineering degrees granted by U.S. universities to non-citizens.[48]

Others assert that there is no broad shortage of scientists and engineers and that increases in the number of graduates with S&E degrees might create or add to surpluses of S&E workers. They argue that traditional indicators of labor shortages (such as rapid job growth, low unemployment rates, and rapid wage increases), as well as historical and projected occupational growth rates, do not support the assertion of the existence or imminent emergence of a shortage. Others argue that the United States graduates a sufficient number of scientists and engineers, but that they choose alternative careers. Still others assert that labor markets, like other markets, will, if allowed to operate freely, adjust to any supply and demand imbalances that may exist.

Supporters and opponents of the doubling effort have raised concerns that rapid expansion of research could unintentionally result in more students pursuing PhDs and post-doctorate work

[46] CRS analysis of data from the National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 2013–15*, NSF 15-325, Table 33 and Table 76, June 29, 2015. CRS has chosen to use the 2013 data from this report as it is the latest year for completed transactions; the report's 2014 and 2015 data are based on NSF estimates.

[47] The number of physical sciences and engineering bachelor's degrees awarded as a percentage of all bachelor's degrees fell from 9.5% in 1985, to a 40-year low of 5.5% in 2008; the percentage has remained at or below 5.7% through 2012. In contrast, the number of PhDs awarded in physical sciences and engineering as a percentage of all PhDs rose to a 43-year high of 25.5% in 2007. Source: CRS analysis of National Science Foundation data, *Science and Engineering Degrees: 1966–2012*, NSF 15-326, June 30, 2015, http://nsf.gov/statistics/2015/nsf15326/#chp2.

[48] Temporary visa holders earned more than one-third (37.3%) of all PhDs granted in physical sciences and more than half (51.4%) of all engineering PhDs in 2012.

than can be sustained if PS&E research funding eventually returns to a lower level. As discussed earlier, the boom-bust cycle of the NIH doubling is thought to have decreased student interest in pursuing life sciences graduate studies and reduced employment prospects for the large number of biomedical researchers with advanced degrees.

Options for Congress

To date, appropriations for the targeted accounts have fallen short of the doubling targets set forth by Congress and Presidents Obama and Bush. In part, this has been due to mounting fiscal pressures on the federal budget and competing demands for federal resources. Increased attention on the federal deficit, national debt, and/or slow economic growth may further reduce the ability and inclination of Congress to expand funding for the targeted accounts.

Among the options available to Congress for addressing the perceived U.S. underinvestment in physical sciences and engineering research are the following.

- **Change the focus from doubling to sustained and predictable funding.**
- **Fully fund the doubling effort.** Fully fund the targeted accounts to achieve nominal doubling over some defined period. Such an undertaking might require either higher overall spending or reductions in other spending. Offsetting reductions might come from other fields of R&D (e.g., life sciences, social sciences) or from non-R&D accounts.
- **Provide less funding than doubling would require.**
    - **Increase funding, but more slowly.** Grow the targeted accounts at a pace below that required to meet the articulated doubling periods.
    - **Keep funding flat, but protect from cuts.** Maintain current funding levels for the targeted accounts or increase them in line with inflation. If Congress pursues deficit reduction through spending cuts, this could require sparing these accounts from cuts that many other accounts may receive.
    - **Cut funding.** Reduce funding for the targeted accounts as part of overall federal deficit reduction, or if other priorities are deemed more important, either permanently or for some period of time until the budget situation improves or priorities change.
- **Change the focus of PS&E funding.**
    - **Shift composition of current PS&E funding.** Reduce PS&E applied research and/or development in order to increase PS&E basic research. Alternatively, funding might be shifted from basic PS&E research toward applied research and development to place a stronger emphasis on commercialization.
    - **Align programs with clearly defined innovation and competitiveness goals.** Within current PS&E funding, change programs to align them more closely with the overarching goals of the doubling effort (i.e., U.S. innovation, competitiveness, economic growth, job creation).
- **Use mechanisms other than federal PS&E funding to achieve competitiveness goals.**
    - **Promote cooperative research.** Identify and adopt new mechanisms that promote expanded cooperative research and technical collaboration among industry, academia, the federal government, and state governments, and more effective approaches to technological innovation.
    - **Further incentivize the private sector.** Explore other mechanisms for meeting the economic goals of the doubling effort by further incentivizing

private sector efforts (e.g., increasing or modifying the research and experimentation tax credit).[49]

- **Increase access to, and use of, foreign research.** Identify and adopt mechanisms by which the United States might promote increased access to and use of PS&E research performed in other nations.

In weighing these options, it might be useful for Congress to consider the potential short, medium, and long-term consequences, if any, of failing to achieve the doubling targets; whether additional funding for PS&E basic research is appropriately characterized as consumption or investment and how that might affect funding decisions; how funding for the effort to increase funding for physical sciences and engineering basic research compares to competing national priorities in the context of the overall federal budget; and to what extent an increase in funding for the physical sciences and engineering basic research is likely to meet competitiveness and other economic challenges in contrast to other approaches.

[49] Often referred to as the "R&D tax credit," development expenditures are not eligible for the credit. For more information, see CRS Report RL31181, *Research Tax Credit: Current Law and Policy Issues for the 114th Congress*, by (name redacted)

Appendix. Authorizations, Requests, and Appropriations for the Doubling Agencies

Table A-1. Authorizations, Requests, and Appropriations, FY2006-FY2016

(in millions of current dollars)

	FY2006	FY2007		FY2008			FY2009			FY2010		
Targeted Accounts	**Actual**	**Request**	**Actual**	**Auth. (P.L. 110-69 and P.L. 109-58)[a]**	**Request**	**Actual**	**Auth. (P.L. 110-69 and P.L. 109-58)[a]**	**Request**	**Actual**	**Auth. (P.L. 110-69)**	**Request**	**Actual**
NSF	5,589.1	6,020.2	5,889.9	6,600.0	6,429.0	6125.3	7,326.0	6,854.1	6,493.6	8,132.0	7,045.0	6,872.5
DOE/SC	3,602.0	4,101.7	3812.8	4,586.0	4,397.9	4,088.8	5,200.0	4,722.0	4,772.6	5,814.0	4,941.7	4,829.1
NIST (STRS and CRF)	568.4	535.0	493.1	653.0	594.4	601.0	628.3	634.0	644.0	634.5	651.5	662.0
Total	**9,759.5**	**10,656.9**	**10,195.7**	**11,839.0**	**11,421.3**	**10,815.1**	**13,154.3**	**12,210.1**	**11,910.1**	**14,580.5**	**12,638.2**	**12,363.6**

	FY2011			FY2012			FY2013			FY2014	
Targeted Accounts	**Auth. (P.L. 111-358)**	**Request**	**Actual**	**Auth. (P.L. 111-358)**	**Request**	**Actual**	**Auth. (P.L. 111-358)**	**Request**	**Actual**	**Request**	**Actual**
NSF	7,424.4	7,424.4	6,806.0	7,800.0	7,767.0	7,033.1	8,300.0	7,373.1	6,884.1	7,625.8	7,171.9
DOE/SC	5,247.0	5,121.4	4,857.7	5,614.0	5,416.1	4,873.6	6,007.0	4,992.1	4,621.1	5,152.8	5,070.2
NIST (STRS and CRF)	709.3	709.3	567.3	746.0	763.5	622.4	798.0	708.0	635.8	753.7	707.0
Total	**13,380.7**	**13,255.1**	**12,231.0**	**14,160.0**	**13,946.6**	**12,529.1**	**15,105.0**	**13,073.2**	**12,141.0**	**13,532.3**	**12,949.1**

	FY2015		FY2016	
Targeted Accounts	**Request**	**Enacted**	**Request**	**Enacted**
NSF	7,255.0	7,344.2	7,723.6	
DOE/SC	5,111.2	5,071.0	5,339.8	
NIST (STRS and CRF)	739.0	725.8	813.7	
Total	**13,105.2**	**13,141.0**	**13,877.0**	

Sources:
Requests: President's budget requests and agency budget justifications for each year.
Actuals: President's budget requests and agency budget justifications published two years later (e.g., FY20011 actuals from the President's budget request FY2013).
Auth. (Authorizations): America COMPETES Act (P.L. 110-69); FY2008-FY2010, America COMPETES Reauthorization Act (P.L. 111-358), FY2011-FY2013; and Energy Policy Act of 2005 (P.L. 109-58).

Notes: Totals may differ from the sum of the components due to rounding. Figures in this table have been revised since the original date of publication in this report due to methodological changes.

a. For FY2008 and FY2009, authorization for the Department of Energy Office of Science was provided by P.L. 109-58; authorization for the National Science Foundation and the targeted NIST accounts were provided by P.L. 110-69.

Table A-2. Federal Obligations for Basic Research in Physical Sciences, Engineering, and PS&E Combined, FY2006 and FY2013

(in thousands of current dollars, actual)

	FY2006			FY2013		
	Physical Sciences	**Engineering**	**PS&E**	**Physical Sciences**	**Engineering**	**PS&E**
Total Federal Funding	**3,515,545**	**2,364,580**	**5,880,125**	**4,432,226**	**3,407,547**	**7,839,772**
Doubling Agencies						
DOE SC	1,477,624	521,321	1,998,945	1,687,395	884,918	2,572,313
NIST	63,705	3,755	67,460	140,227	24,900	165,126
NSF	722,439	492,992	1,215,431	865,381	614,836	1,480,216
Subtotal, Doubling Agencies	**2,263,768**	**1,018,068**	**3,281,836**	**2,693,002**	**1,524,654**	**4,217,655**
Share of Federal Total	*64.4%*	*43.1%*	*55.8%*	*60.8%*	*44.7%*	*53.8%*
Other Selected Agencies						
DOD	194,036	426,313	620,349	400,973	583,208	984,180
DOE NNSA	2,329	3,996	6,325	32,974	1,223	34,198
NASA	709,506	333,874	1,043,380	1,111,656	522,485	1,634,140
NIH	219,981	525,157	745,138	83,356	727,165	810,521
Subtotal, Other Selected Agencies	**1,125,852**	**1,289,340**	**2,415,192**	**1,628,958**	**1,834,080**	**3,463,039**
Share of Federal Total	*32.0%*	*54.5%*	*41.1%*	*36.8%*	*53.8%*	*44.2%*

Source: CRS analysis of data from the National Science Foundation, National Center for Science and Engineering Statistics, *Survey of Federal Funds for Research and Development, FYs 2013–15*, NSF 15-324, Table 34, June 29, 2015.

Notes: DOE SC = Department of Energy Office of Science; NIST = National Institute of Standards and Technology; NSF = National Science Foundation; NASA = National Aeronautics and Space Administration; NNSA = Department of Energy National Nuclear Security Administration; DOD = Department of Defense; NIH = National Institutes of Health.

Table A-3. Federal Obligations for Applied Research in Physical Sciences, Engineering, and PS&E Combined, FY2006 and FY2013

(in thousands of current dollars, actual)

	FY2006			FY2013		
	Physical Sciences	**Engineering**	**PS&E**	**Physical Sciences**	**Engineering**	**PS&E**
Total Federal Funding	**1,835,560**	**6,314,150**	**8,149,710**	**1,849,675**	**7,540,686**	**9,390,361**
Doubling Agencies						
DOE SC	0	0	0	8,832	49,824	58,656
NIST	67,095	135,814	202,909	59,684	144,246	203,930
NSF	6,653	172,823	179,476	7,105	255,356	262,460
Subtotal, Doubling Agencies	**73,748**	**308,637**	**382,385**	**75,620**	**449,426**	**525,046**
Share of Federal Total	*4.0%*	*4.9%*	*4.7%*	*4.1%*	*6.0%*	*5.6%*
Other Selected Agencies						
DOD	434,242	2,617,397	3,051,639	338,081	2,240,149	2,578,230
DOE NNSA	795,515	791,762	1,587,277	935,527	853,653	1,789,180
NASA	142,932	929,348	1,072,280	252,905	1,644,139	1,897,044
NIH	170,307	406,571	576,878	71,087	620,134	691,221
Subtotal, Other Selected Agencies	**1,542,996**	**4,745,078**	**6,288,074**	**1,597,600**	**5,358,075**	**6,955,675**
Share of Federal Total	*84.1%*	*75.1%*	*77.2%*	*86.4%*	*71.1%*	*74.1%*

Source: CRS analysis of data from the National Science Foundation, National Center for Science and Engineering Statistics, *Survey of Federal Funds for Research and Development, FYs 2013–15*, NSF 15-324, Table 35, June 29, 2015.

Notes: DOE SC = Department of Energy Office of Science; NIST = National Institute of Standards and Technology; NSF = National Science Foundation; NASA = National Aeronautics and Space Administration; NNSA = Department of Energy National Nuclear Security Administration; DOD = Department of Defense; NIH = National Institutes of Health.

Table A-4. Federal Obligations for Research (Basic and Applied) in Physical Sciences, Engineering, and PS&E Combined, FY2006 and FY2013

(in thousands of current dollars, actual)

	FY2006 (actual)			FY2013 (actual)		
	Physical Sciences	Engineering	PS&E	Physical Sciences	Engineering	PS&E
Total Federal Funding	**5,351,105**	**8,678,730**	**14,029,835**	**6,281,901**	**10,948,233**	**17,230,133**
Doubling Agencies						
DOE SC	1,477,624	521,321	1,998,945	1,696,227	934,742	2,630,969
NIST	130,800	139,569	270,369	199,911	169,146	369,056
NSF	729,092	665,815	1,394,907	872,485	870,191	1,742,677
Subtotal, Doubling Agencies	**2,337,516**	**1,326,705**	**3,664,221**	**2,768,622**	**1,974,079**	**4,742,701**
Share of Federal Total	*43.7%*	*15.3%*	*26.1%*	*44.1%*	*18.0%*	*27.5%*
Other Selected Agencies						
DOD	628,278	3,043,710	3,671,988	739,054	2,823,357	3,562,410
DOE NNSA	797,844	795,758	1,593,602	968,502	854,876	1,823,378
NASA	852,438	1,263,222	2,115,660	1,364,561	2,166,624	3,531,184
NIH	390,288	931,728	1,322,016	154,443	1,347,299	1,501,742
Subtotal, Other Selected Agencies	**2,668,848**	**6,034,418**	**8,703,266**	**3,226,559**	**7,192,155**	**10,418,714**
Share of Federal Total	*49.9%*	*69.5%*	*62.0%*	*51.4%*	*65.7%*	*60.5%*

Source: CRS analysis of data from the National Science Foundation, National Center for Science and Engineering Statistics, *Survey of Federal Funds for Research and Development, FYs 2013–15*, NSF 15-324, Table 35, June 29, 2015.

Notes: DOE SC = Department of Energy Office of Science; NIST = National Institute of Standards and Technology; NSF = National Science Foundation; NASA = National Aeronautics and Space Administration; NNSA = Department of Energy National Nuclear Security Administration; DOD = Department of Defense; NIH = National Institutes of Health.

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