The America COMPETES Act:
History, Overview, & Implementation*

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Abstract

The America COMPETES Act (ACA) was one of the most salient bipartisan legislative achievements of the past decade and, potentially, one of the most notable pieces of science and innovation policy of the new millennium. To date, however, limited systematic evaluation of the America COMPETES Act has been undertaken. This paper supports efforts to evaluate the ACA by providing an overview of the history, goals, and implementation 2007 America COMPETES Act (ACA07) and the 2010 America Competes Reauthorization Act (ACA10). The paper highlights the initial aims of the Acts and examines the programs and policies which have received subsequent funding and support. Although the America COMPETES Act was introduced with bipartisan support, fanfare from the business community, and plaudits from the science policy community, the tangible outputs of the Act and its subsequent Reauthorization appear limited, although a number of notable programs have been created.

I. Introduction

The America COMPETES Act (ACA) was one of the most salient bipartisan legislative achievements of the past decade and, potentially, one of the most notable pieces of science and innovation policy of the new millennium. To date, however, limited systematic evaluation of the America COMPETES Act has been undertaken. This paper supports efforts to evaluate the ACA by providing an overview of the history, goals, and implementation 2007 America COMPETES Act (ACA07) and the 2010 America Competes Reauthorization Act (ACA10). The paper highlights the initial aims of the Acts and examines the programs and policies which have received subsequent funding and support. Although the America COMPETES Act was introduced with bipartisan support, fanfare from the business community, and plaudits from the science policy community, the tangible outputs of the Act and its subsequent Reauthorization appear limited, although a number of notable programs have been created.

II. Historical Context: Arguments for S&T funding in the U.S. over time

2.1 Background: The argument for national science and innovation funding

Although the aim of "promot[ing] the progress of science and useful arts" was articulated in the U.S. Constitution as a power of Congress, this power was expressly linked to providing incentives to authors and inventors.[1] Consistent with the specificity of these aims, the U.S. federal government did not engage in much centralized policy-making regarding science and technology in its first century of existence. The federal government did, indeed, administer the patent system throughout the 18th and 19th centuries. During and following the Civil War, the federal government began to expand its role in promoting science and technology by developing some key institutions. The Morrill Act of 1862 created the mechanism for founding dozens of land-grant colleges, dedicated to practical research and teaching,

1 *U.S. Constitution*, Article I, Section 8, Clauses 1 & 8: "The Congress shall have Power…To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries." Clause 1 precedes the ellipsis, while Clause 8 follows.

particularly in agriculture and mechanics.[2] Passed during the Civil War (earlier efforts had failed in part because of the resistance of southern states), the 1862 Act, led to the creation of institutions in the north. Following the Civil War, eligibility was extended to former Confederate states as well. Related, subsequent acts of Congress expanded the federal role in supporting states' higher education efforts, including the Hatch Act of 1887, which provided funding for agricultural experiment stations at land-grant colleges, and the Morrill Act of 1890, which expanded the prior Morrill Act and led to additional funding for existing land grant colleges and the foundation of new land grant colleges (though with cash grants rather than land), especially in the south. The National Academy of Sciences (NAS) was also established during the Civil War (in 1863) as a quasi-governmental science agency, aimed at providing counsel to government agencies on scientific matters.

The second major wave of federal science- and technology-related investments occurred during the first two decades of the 20th century and accelerated during World War I. The federal government established the National Bureau of Standards (the predecessor to the National Institute of Standards & Technology) in 1901, the Public Health Service in 1912, and the National Advisory Committee for Aeronautics in 1915. The Naval Consulting Board was established in 1915 to support the assessment and development of military technology, and the National Research Council was created the following year as a research organization to provide scientific and technical advice to the government, particularly by conducting studies of relevance the National Academy of Science.

The argument for government participating more actively in funding and guiding basic scientific research was made famously by Vannevar Bush, Director of the Office of Scientific Research and Development under Franklin Delano Roosevelt during World War II, in his monograph, *Science: The Endless Frontier*. Bush argued both that the scientific enterprise was a key to economic growth and improvements in social welfare and that responsibility for funding basic science lay, ideally, with the

[2] Nevins, A. (1962) *The State Universities and Democracy*, Urbana, IL: University of Illinois Press

federal government.[3] His logic for suggesting federal support for science funding was straightforward and reflected an understanding of positive externalities: Since investments in basic scientific research invariably diffuse to other organizations in way that limits the ability to reap sufficient returns from such investments, for-profit organizations face lower incentives to invest in basic research than does society overall – i.e., basic research can be usefully classified as a public good. In order to overcome this market failure and ensure socially efficient investment in science, Bush argues, government should step into the void and assume an active role in supporting scientific research. Bush's vision resulted in the creation of the National Science Foundation in 1950 and has constituted the rationale for government investment in basic science since that time.[4]

2.2 The Competitiveness Agenda: National science and technology investments in a connected world

The line of argument built on Vannevar Bush's logic – i.e., that the federal government should play a role in funding science and technology and that science and technology leadership helps fuel economic growth and national prosperity – has become particularly salient over the past two decades in discussions of national competitiveness. The Bush argument is particularly compelling in a world in which only one country has a substantial edge in the creation of useful knowledge (relative to other countries) or if the worldwide investments in science were coordinated. If the world, or the unchallenged

3 "Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of the common man for ages past. Advances in science will also bring higher standards of living, will lead to the prevention or cure of diseases, will promote conservation of our limited national resources, and will assure means of defense against aggression." (Bush, XXX)

4 Building on Bush's ideas, economists beginning with Nelson (1959) and Arrow (1962) described as a public, non-rivalrous, non-excludable good which creates higher social welfare than private benefits. Non-rivalrous goods are those for which the costs of transmission and use are zero – i.e., they can be consumed by multiple individuals or organization without the creation of additional costs. Non-excludable good are those that could be easily imitated by rival producers and cannot be easily protected via trade secrets or other mechanisms. For organizations of relatively similar capabilities, scientific knowledge is both relatively non-rivalrous good and non-excludable (although some investments are needed to be able to access or apply scientific knowledge and some scientific knowledge can be effectively protected by secrecy, tacitness, or hoarding research materials). As a result, markets for basic science (and technological knowledge that is far from commercialization) are likely to lead to underinvestment in research and underprovision of inventions and innovations relative to the social ideal. Considering the central role of scientific and technical knowledge play a central role in economic growth and social welfare (Solow, 1956; Abramovitz, 1956), the fact that scientific knowledge evidences the properties of a public good strongly suggest that the creation and accretion of knowledge should be central goals for national policymakers.

leader country, were to curtail investments in science and technology or slow the rate at which it built on prior research advances, technological improvements would stagnate, as would economic growth.[5] In the event, however, that a number of countries have relatively similar levels of scientific development, national decisions regarding scientific investment become more interrelated. This complicates matters, as one country's optimal investment decisions will depend on the investments of other nations and on the rapidity and completeness with which knowledge diffuses. If scientific and technical knowledge diffuses slowly and incompletely (or if it is particularly expensive for non-innovator countries to imitate leader countries, i.e., if catch-up is slow), then a leader country is likely to obtain high returns to its investments in science. If, however, scientific and technical knowledge diffuses sufficiently swiftly and effectively, then there may not be a substantial benefit to being a leader country, as fast-follower countries can free ride on the investments of leaders.

Thus, it will only be valuable for a country to pursue a strategy of scientific and technical leadership in the presence of increasing returns and local knowledge diffusion. Stated somewhat differently, in order for locally-generated knowledge to be translated into scientific and/or technical leadership, researchers in close proximity to an original discovery must be able to exploit that discovery more rapidly and more intensively than researchers at a greater distance.[6]

Despite improvements in information technology that have lowered the communication costs and made it easier to spread information, the often anticipated "death of distance" has failed to materialize. Indeed, proclamations that the world is flat (Friedman, 2005) overlook the importance of local knowledge spillovers, which are quite strong, even in science, one of the areas in which ideas are most likely to flow most effectively. While transportation costs have declined for physical goods and cost of direct communication has also declined, empirical evidence suggests value of proximity has increased in most industries and most sectors as well. Research suggests that investments in science and technology at the

5 See Jones, Charles I. (1995) "R&D Based Models of Economic Growth," *Journal of Political Economy,* 103: 739-784.
6 Furman, Jeffrey L. (2011) "The Economics of Science and Technology Leadership," *Leadership in Science and Technology*: *A Reference Handbook,* William Sims Bainbridge, Editor, Sage Publications, Chapter 3.

world's frontier yield spillovers that are constrained to geographically proximate regions (Jaffe, Trajtenberg, & Henderson, 1993) and that even small barriers to diffusion can explain large differences in productivity levels among the most advanced nations (Eaton & Kortum, 1999). Thus, there are at least some reasons to believe that investments in scientific and technical leadership may yield high rates of return than investments encouraging fast-follower approaches. Within the United States, those regions that have been historically knowledge-intensive have experienced greater economic success, even as the information economy has developed further (Glaeser and Ponzetto (2009) "Did the Death of Distance Hurt Detroit and Help New York?" NBER WP #13710). More broadly, research suggests that those countries and geographic regions that have invested most heavily in scientific and technological infrastructure and adopt innovation-oriented policies have substantially improved their science bases and innovative capacity (Furman and Hayes, 2004). The evidence suggests, though, that while many leader countries have continued to make science and technology investments at increasing rates, a number of former follower countries have increased their commitments to innovation at even greater rates. This has contributed to the globalization of science and technology and has contributed to the erosion of the gap between the leader and emerging innovator countries.

There remains, however, a relative paucity of theoretical and empirical evidence adjudicating whether country-level investments in scientific and technical leadership have higher average and marginal rates of return than investments in diffusion, imitation, and catch-up. Nonetheless, the prevailing public policy consensus within the United States remains that national science and technological leadership is welfare-enhancing (Council on Competitiveness, 2012; World Competitiveness Report, 2012). Although outward support for science and technology investment remains strong, there is evidence that public support for U.S. S&T investment may be waning, both from certain political pronouncements and from Congressional actions regarding science and technology funding.[7]

[7] The sentiments expressed by Rep. Lincoln Diaz-Balart (R-FL) during a May 2010 hearing regarding the reauthorization of the America COMPETES Act demonstrate both the public support for science funding and the increasing doubts regarding its rate of return: "I understand and I support the underlying principles of the America COMPETES Act, prioritizing and strengthening investments in basic research and development and STEM: science, technology, engineering, and mathematics

2.3 U.S. investment in science & innovation at the turn of the millennium: A storm on the horizon?

Concerns regarding the competitiveness of the United States economy have been most salient during periods of recession have been most closely linked with rapidly-growing countries with which the United States has a negative trade balance. The two most notable of these periods include the 1980s, when the Japanese economy appeared more robust than the U.S. economy, and the most recent half-decade, during which Asian economies, especially particular regions of China and India, have achieved higher rates of growth.

Fears about U.S. competitiveness in the 1980s and early 1990s subsided somewhat as Japan entered into its "Lost Decade," as the United States economy achieved increased real growth rates coupled with low inflation during the Clinton presidency, and, at the end of the 1990s, as the internet boom resulted in substantial new firm formation and coincided with a period of increasing productivity. Questions regarding U.S. commitment to science and technology investments did emerge during this period, however (Porter and Stern, 1999, and Furman, Porter, Stern, 2002). Despite its macroeconomic difficulties, Japanese firms continued to invest heavily in research and development and the Japanese government did not substantially divert funding from S&T activities. Some countries increased commitments to science and technology at rates that exceeded those of the United States (Council on Competitiveness, 2001), raising concerns about U.S. science and technical leadership going forward.

With the internet boom of the late 1990s and associated wave of advances in consumer electronics, software, and computer hardware, the growing extent of science and technology globalization

education. . . . as much as I would prefer to support the underlying legislation, I believe that at this time of severe budgetary constraints, the underlying legislation includes excessive spending levels. The bill has an overall authorization of nearly $86 billion, which represents approximately $20 billion in new funding above the fiscal base of this year. That is a significant increase when we're facing record budget deficits. And that is after the so-called stimulus bill injected six billion additional dollars into the agencies funded by this bill. … And if we continue on that trajectory, the America that we know, love, and admire will be severely threatened. Our excessive spending threatens the very foundation of our economy and our way of life. We could very well find ourselves in a position, soon, similar to today's Greece," Richard M. Jones (2010) "Selections from the Floor: House Consideration of COMPETES Legislation," The American Institute of Physics Bulletin of Science Policy News, 56.

became clear. South Korean companies, like Samsung and LG, emerged as technology leaders, as did Finnish firm Nokia. Large numbers of high technology ventures arose in Israel, Taiwan, Singapore, China, and India, among other countries. These private sector successes reflected significant public investments in science and technology infrastructure and increasing national commitments to S&T.

These successes raised questions in the United States regarding its future leadership in innovation. In 2005, following joint discussions between the National Academy of Sciences and the National Academy of Engineering and official requests from members of both houses of the U.S. Congress, the National Academies initiated a study of U.S. competitiveness that focused on national investments in science and technology. The aim of the effort was to develop specific recommendations that could support American competitiveness and prosperity in the 21st century. The resulting report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (commonly referred to as, the *Gathering Storm* report), included a core evaluation of 224 pages and was bolstered by more than three hundred pages of appendices.[8] The report assessed U.S. performance in science and technology investment and productivity, considered actions that the country should take to improve (a) K-12 education in science and mathematics, (b) science and engineering research, (c) science and engineering higher education, and (d) economics and technology policy in order to ensure future prosperity, and discussed the implications of the United States losing is competitive advantage in science and technology.

Based on its analysis, the report made four general recommendations and specified twenty "implementation actions" for achieving those goals. The set of recommendations, including both general and specific recommendations, appears in Table 1. Some of the report's more notable recommendations included:

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[8] Committee on Prospering in the Global Economy of the 21st Century (2005) *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, Committee on Science, Engineering, and Public Policy (COSEPUP), National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the national academies, The National Academies Press: Washington, DC.

- increasing federal investment in basic R&D by 10% per year for each of the next seven fiscal years
- substantial increases in investments in STEM education by increasing funding for science and math teaching and student recruiting
- creating the Advanced Research Projects Agency-Energy (ARPA-E) based on the Defense Advanced Research Projects Agency (DARPA) model
- increasing scholarship funding for U.S. citizens in areas of national need; supporting the ability of international graduate students to obtain visas and stay in the United States following completion of their studies
- enhancing intellectual-property protection and providing pro-innovation tax incentives
- ensuring broadband internet access.

The *Gathering Storm* report was not the only effort at the time turning the spotlight on the issue of science and technology leadership. A number of the members of the National Academies *Gathering Storm* report authorship team, including Charles Vest and Norman Ackerman, had participated in the Council on Competitiveness's *National Innovation Initiative Summit* in May 2004, the summary of which, "Innovate America," demonstrated many of the same concerns as those reported in the National Academies report.[9]

Concerns about American competitiveness and relative investments in science and technology were further integrated into policymaking discussions when President George W. Bush announced the American Competitiveness Initiative (ACI) in his January 2006 State of the Union Address. The ACI incorporated a number of the *Gathering Storm* recommendations, including a call for doubling the nation's investment in funding for the physical sciences. Unlike the original Gathering Storm plan, which

[9] Council on Competitiveness (2005) ""Innovate America: National Innovation Initiative Summit and Report."

called for a 10% annual increase in funding over a seven year period, the ACI proposed a 7% increase in funding over a 10 year period.[10]

III. The America COMPETES Act of 2007

3.1 ACA2007: Overview of key provisions

Congress began to take actions to implement various aspects of the *Gathering Storm* recommendations in late 2005 and throughout 2006. President Bush's American Competitiveness Initiative gave further momentum to these efforts. Related bills made their way through the House of Representatives and Senate between May and August 2007 and culminated with the August 2007 the passage of the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act of 2007 (America COMPETES Act, ACA-07). Sponsored by Barton Gordon (D-TN) and co-sponsored by twenty-one representatives, including fifteen Democrats and six Republicans, the ACA received bi-partisan support throughout this period and was passed by an overwhelming majority of the both the House of Representatives and via unanimous consent in the Senate.[11] The bill was signed into law by President George W. Bush on August 9, 2007, although he expressed the, "[concern] that the legislation includes excessive authorizations and new duplicative programs."[12] Despite the Administration's reservations, scientific societies and the high tech business community regarded the new law with substantial optimism.[13,14]

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[10] Office of Science and Technology Policy, Executive Office of the President (2006) "American Competitiveness Initiative Research and Development Funding in the President's 2007 Budget," White House http://www.whitehouse.gov/files/documents/ostp/pdf/1pger_aci.pdf, accessed 21 February 2012).

[11] Govtrack.us, "H.R. 2272: America COMPETES Act," http://www.govtrack.us/congress/bill.xpd?bill=h110-2272; accessed March 2012.

[12] White House Press Release, August 9, 2007, "Fact Sheet America Competes Act of 2007, http://georgewbush-whitehouse.archives.gov/news/releases/2007/08/20070809-6.html.

[13] Mervis, Jeffrey (2007) "Congress passes massive measure to support research, education," *Science*, 3117, 736-737 and American Physical Society, 2007, "Supporters of America COMPETES Bill Praise Its Passage, Urge Federal Funding," October 4, 2007; http://www.aps.org/about/pressreleases/competes.cfm; accessed March 2012.

[14] Broache, Anne, "Bush signs off on billions for science, tech," Cnet News, August 9 2007; http://news.cnet.com/8301-10784_3-9757778-7.html, accessed March 2012.

The Act was broad in scope but focused in its overarching aims. Specifically, the Act aimed (1) to enhance the United States' overall levels of investments in science and engineering research, particularly in areas other than biomedical research, which was already perceived to be well-funded, and (2) to improve education for science, technology, engineering, and mathematics (STEM) in American schools (K-12) and post-secondary institutions. To further these goals, the Act authorized $33.6 billion in funding between fiscal years 2008 – 2010. The Act consisted of eight sections ("titles"), the first seven of which articulated responsibilities and funding authorizations for the affected federal agencies and offices: Office of Science & Technology Policy (OSTP) and government wide science; National Aeronautics and Space Administration (NASA); National Institute of Standards & Technology (NIST); Ocean and Atmospheric Programs; Department of Energy; Education; National Science Foundation (NSF); General Provisions.[15] In addition to articulating additional responsibilities for various government agencies, the Act authorizes spending for new and existing but modified programs.

Reviewing the federal budget process is helpful for understanding the nature and implications of the America COMPETES Act. The rules of Congress involve a two-stage procedure for providing funding for federal agencies and programs. In the first step, Congress must pass legislation that *authorizes* the creation, continuation, or modification of federal programs and agencies. This can be reasonably viewed as a policy-making step, as authorizations are under the jurisdiction of relevant legislative committees (e.g., the House Committee on Science, Space, and Technology) and involve setting funding targets (ceilings) for particular programs. In the second step, the Congressional budgeting process results in *appropriations* bills that determine specific levels of funding for authorized federal agencies and programs.[16] These bills are subject to the jurisdiction of the House and Senate Appropriations Committees, which are not obligated to provide complete funds for all authorized

[15] 110th Congress (2007) "America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act, H.R. 2272, Government Printing Office: Washington, DC.

[16] Rules in the House of Representatives stipulate that authorization acts and appropriation acts must be separate and that the appropriations process cannot approve funding in excess of the amounts (if any) specified in the authorization legislation. Senate rules also follow the practice of separating authorizations and appropriations, but enable appropriation in authorization bills (Streeter, Sandy (2011) "The Congressional Appropriations Process: An Introduction," *Congressional Research Service,* 97-684).

programs.[17] The 2007 ACA authorized federal funds science and technology programs for a three-year period; thereafter, additional funding would require further acts of Congress. (In 2010, Congress passed the America COMPETES Reauthorization Act, which extended a number of the programs created in the 2007 Act, retired some of the 2007 Act programs, and initiated some new S&T programs.) Historically, federal science and technology programs received funding authorizations from a variety of acts. The ACA was notable as a S&T funding authorization mechanism, as it aggregated funding authorizations across a broad range agencies, identified a series of new S&T programs, and developed a vision for coordination across S&T-focused agencies.

The fact that the 2007 ACA and 2010 ACRA were authorization bills means that they were neither strictly *necessary* nor *sufficient* to ensure funding for the programs associated with them. Moreover, although each Act articulated responsibilities for various Executive agencies, including, for example, the responsibility of the Office of Science and Technology Policy to identify inadequacies at federal laboratories and prioritize investments in federal research infrastructure (Section 1007), the Executive Branch has leeway in the way in which it interprets and adheres to these responsibilities. Thus, a substantial fraction of the promise of the COMPETES legislation depended upon the extent to which Congress subsequently funded the programs described by the Act and the extent to which presidential administrations subsequently adhered to the prescriptions of the Act for the Executive Branch.

I characterize the 2007 Act as involving seven distinguishing features: (1) the Doubling Path; (2) ARPA-E, (3) Science, Technology, Engineering, and Math (STEM) Education, (4) modification of NIST programs, (5) additional programs in other agencies, (6) commitment to high-risk, high-reward basic research projects, and (7) greater coordination of federal science and technology investments. I describe each of these in greater below.

[17] Supplemental appropriations, such as those used for the 2009 American Recovery and Reinvestment Act (ARRA) can modify or extend Congressional funding. Such appropriates are usually invoked in response to natural disasters, national security issues or conflicts, or economic exigencies.

(1) The "Doubling Path": The ACA 2007 authorized spending increases for FY2008-2010 that, if funded and maintained consistently, would lead to a doubling of funding for the National Science Foundation (NSF), the laboratories of the National Institute of Standards and Technology (NIST), and the Department of Energy's Office of Science within seven years. This was consistent with the exhortation of the *Gathering Storm* report, although it was accelerated relative to the Bush Administration's 2006 American Competitiveness Initiative, which called for a ten-year doubling path. Also consistent with the *Gathering Storm* report, the doubling path would be focused on increasing investments in the physical sciences and engineering, rather than the life sciences.[18]

(2) ARPA-E: The ACA authorized the establishment of the Advanced Research Projects Agency – Energy within the Department of Energy. Modeled on the Defense Advanced Research Projects Agency (DARPA) and sharing its naming convention, the agency was envisioned as an agency that would, "identif[y] and promot[e] revolutionary advances in fundamental sciences, translat[e] scientific discoveries and cutting-edge inventions into technological innovations, and accelerat[e] transformational technological advances in areas that industry, by itself, is not likely to undertake because of technical and financial uncertainty."[19] ARPA-E was envisioned as an agency that would fund cutting-edge research aimed at enhancing the U.S.'s ability to develop and sell clean, affordable, and reliable energy. The agency was to target projects in which private industry was unlikely to invest, either because such projects were too risky or because they would generate too many spillovers to ensure sufficiently high private returns. Like DARPA, the organizational structure of ARPA-E was expected to be lean (i.e., to have few organizational layers) and to involve program managers who were world-class technical experts with a strong entrepreneurial orientation who would selectively advance promising projects and approaches. The ACA07

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[18] Richard Freeman and John van Reenen (2009) "What if Congress Doubled R&D Spending on the Physical Sciences?" in Josh Lerner and Scott Stern, eds., Innovation Policy and the Economy, Volume 9, University of Chicago Press, 1-38.

[19] Stine, Deborah D. (2009) "America COMPETES Act: Programs, Funding, and Selected Issues," *Congressional Research Service*, RL34328.

authorized $300 million for the agency for FY2008 and "such sums as necessary" for FY2009 and FY2010.[20]

(3) Science, Technology, Engineering, Math (STEM) Education: A central motivating force behind the 2007 ACA was the concern that American competitiveness was being eroded (and would continue to be eroded) by relative declines in U.S. extent of investment in STEM education in primary and secondary schools, by the quantity and quality of American STEM graduates, and by the availability of funding for American graduate students. Increased investments in STEM education were to be achieved particularly through programs at the Department of Energy, Department of Education, and National Science Foundation. The Act highlighted three particular areas of focus for new programs: (a) increasing the number of STEM teachers, particularly those of high quality and with exceptional training, and improving the depth of existing teachers' in STEM areas; (b) exposing a larger number of U.S. students to STEM education and attracting more into post-secondary STEM education and STEM-linked careers; and (c) improving investments in STEM education among women, minorities, and high-need schools. The ACA authorized a broad series STEM programs to be developed and implemented by the National Science Foundation (NSF), Department of Energy (DOE), and Department of Education (ED).

- ***Department of Energy (DOE) STEM initiatives:*** The ACA instructs the Department of Energy to appoint a Director Science, Engineering, and Mathematics Education to oversee STEM education initiatives within the DOE. The Act also establishes a number of new STEM programs for the Director to oversee. These include (a) programs for establishing state-wide public schools specializing in math and science education, (b) a summer program in math and science for middle and high school students that would involve internships with the national laboratories, and (c) a recruiting and mentoring program in STEM education for women and minority students. In addition to the internship program, the Act authorizes other programs that draw upon the DOE's national laboratories, including a Centers of Excellence

[20] The Homeland Security Advanced Research Projects Agency (HSARPA), established in 2002, is another federal agency devoted to translational research developed on the DARPA model.

program that would enable teachers in a high-need public secondary school proximate to each national laboratory to use the lab's equipment for teaching purposes and summer programs delivered at the national laboratories designed to improve the teaching skills of K-12 teachers. At the post-secondary level, the ACA also called for the creation of the a graduate research fellowship program, the Protecting America's Competitive Edge (PACE) fellowship, dedicated to funding researchers operating in the DOE's domain.

- ***Department of Education (ED) STEM initiatives:*** The ACA authorized funding for a number of matching grant programs, including programs dedicated to creating part-time master's degree programs in STEM fields, one-year master's degrees that would enable STEM professionals to achieve teaching certification associated fields, and educational partnerships that would facilitate teaching certification in STEM fields. Most notably, matching grants were authorized to support the teaching of advanced placement or international baccalaureate courses (AP/IB) in STEM fields in low income or rural areas and to facilitate the enrollment of students in such courses. Another matching grant program, which, like the AP/IB program had been part of President Bush's American Competitiveness Initiative was authorized by the ACA was the Math Now initiative. This program (authorized by Section 6201) of the ACA07, provided matching grants to high-need local educational agencies to support research-based mathematics teaching initiatives, enhance math teachers' professional development opportunities, and monitor and support of K-9 student progress in mathematics. Three additional STEM-related grant programs authorized by the ACA were the Foreign Language partnership program, which supported study in foreign languages valuable for national competitiveness and security reasons; the Alignment of Education programs, which were designed to ensure a strong match between K-12 STEM educational content and the knowledge and skills requirements of post-secondary STEM education and the workforce; and the Mathematics and Science Partnership Bonus awards, designed to be bestowed on schools with low-income students that evidenced the most significant progress in math and science education.
- ***National Science Foundation (NSF) STEM initiatives:*** The 2007 ACA authorized the expansion of a number of NSF STEM programs, including: the Robert Noyce Teacher Scholarship program, which provides scholarships for STEM majors who agree to serve as teachers in high-need schools for at least two years after graduation; the Math & Science Partnership program; the STEM Talent Expansion Program (STEP) and Advanced Technological Education (ATE) program, which aimed to increase the number and quality of

college graduates in STEM fields, respectively; the Graduate Research Fellowship and Integrative Graduate Education and Research Traineeship (IGERT) programs, which support research funding and educational innovation among STEM graduate school programs. The ACA also includes a number of provisions designed to support the participation of women and historically-underrepresented minorities in STEM training. The ACA also authorized the creation of a new NSF program, the Laboratory Science Pilot program (LSP), a program designed to award grants to partnerships between higher education and other organizations that would improve schools' laboratories, instruments, and tools.

(4) ***Modification of National Institute of Standards & Technology (NIST) programs:*** The ACA created or modified a number of science and engineering programs under the purview of the National Institute of Standards and Technology.

- ***Hollings Manufacturing Extension Partnership Program (MEP)***: NIST's Manufacturing Extension Partnership program operates a nationwide network of regional centers, supported by federal and non-federal funding sources, that provide scientific, technical, and management assistance to small- and medium-sized enterprises. The ACA authorized the establishment of additional MEP programs, such as collaborative research grants, a fellowship program, and a research database.
- ***Replaced the Advanced Technology Program (ATP) with the Technology Innovation Program (TIP):*** Established in 1998 and first funded in 1990, the ATP involved providing up to 50% federal support for firm-based research projects that were assessed as both having high potential for private returns and being too distant from commercialization to adequately attract private investment. The remainder of support for such projects was obtained by other funding sources, including matching grants and private funding. Budget support and political support for the ATP varied substantially over the course of its existence.[21] The 2007 ACA authorized replacing the ATP with the Technology Innovation Program, targeted for small- and medium-sized enterprises and ventures involving such enterprises and either private sector, academic, or non-profit collaborators. Similar to the ATP, the TIP was designed to provide federal support (subject to matching funds) for high-risk, transformational research that addressed areas of specific national need.

[21] Fong, Glenn R. (2001) "Repositioning the Advanced Technology Program," *Issues in Science & Technology Online.*

- ***Fellowship programs:*** In addition to these programs, the ACA authorized funding for NIST to substantially expand its support for postdoctoral and senior research fellowships at NIST in the manufacturing sciences.

(5) ***Additional programs in other agencies:*** The Act creates additional obligations for the White House Office of Science and Technology Policy (OSTP), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA). The OSTP is charged with multiple provisions, including convening a National Science and Technology Summit to evaluate U.S. STEM efforts, creating a President's Council on Innovation and Competitiveness, fostering twice-annual STEM Days in American elementary and middle schools, developing research efforts in "service science," and coordinating efforts across federal agencies to develop STEM education plans, promote innovation and competitiveness, and share innovation-related data and results across agencies. In addition to charging NASA with participation in efforts to coordinate innovation and competitiveness efforts with other agencies, the Act requires NASA to develop an educational project based on the International Space Station (ISS) and to develop a proposal for funding research to be performed on the ISS. The Act expresses the expectation that the NOAA coordinate with other agencies in STEM education efforts, competitiveness, and innovation promotion; contribute to U.S. competitiveness in ocean and atmospheric science and innovation; and develop plans to educate American students regarding the issues covered by the NOAA's research mission.

(6) ***High-risk, High-Rewards Basic Research Projects:*** The Act expressed the "sense of Congress" that each executive agency to which funds were authorized should devote an "appropriate" fraction of its research budget to projects deemed to be high-risk, high-reward efforts. The Act described such projects as "transformative" research, which involves fundamental scientific or technical issues, multidisciplinary efforts, and substantial novelty. This initiative is based on the idea that project-focused funding mechanisms may underinvest in such efforts, which are likely to be more complicated, involve longer-term investments, and have higher variance in outcomes than step-by-step research efforts.

(7) ***Greater coordination of federal science and technology investments:*** Embodied in the 2007 ACA was an effort to effect greater coordination of federal science and technology investments. The Act identifies a number of such responsibilities for the Office of Science and Technology, including the responsibility to identify deficiencies in national research infrastructure and to encourage communication regarding research results and data sharing. In nearly every section of the Act, affected agencies are implored to work more closely with each other and participate in interagency coordination efforts.

3.2 ACA Funding & Implementation (2008-2010) and the American Recovery and Reinvestment Act (ARRA)[22]

A key fact regarding the programs created in and authorized for funding by the 2007 ACA is that many programs were not funded at levels that levels that enabled their implementation in the years after the bill was signed into law. Determining the precise extent to which ACA initiatives were funded and implemented is not straightforward. The Act did not articulate funding levels for each program in each year and some agency budgets are not associated with specific, individual line items in national or agency budgets. Moreover, some federal science and technology programs previously authorized by other acts of Congress received authorizations in the 2007 ACA, making it difficult to link precisely the impact of the 2007 ACA on changes in funding. The Congressional Research Service, particularly Science and Technology Specialists, Deborah D. Stine, Heather B. Gonzalez, and John F. Sargent, has undertaken careful efforts to document ACA program funding in CRS reports. Tables 2 and 3 present summaries of these data.

[22] Data reported in this section regarding Congressional authorization and appropriations and Bush Administration budget requests were culled from D. D. Stine (2008) "America COMPETES Act: Programs, Funding, and Selected Issues," *Congressional Research Service*, RL34328, January 22, 2008, and D. D. Stine (2009) "America COMPETES Act: Programs, Funding, and Selected Issues," *Congressional Research Service*, RL3428, April 17, 2009.

Table 2 lists programs authorized for funding in the Act, distinguishing those that received funding in FY2009 from those that appear not to have received funding in that year (or in FY2008). Table 3 lists programs with specific authorized budgets in the 2007 and 2010 America COMPETES Act and identifies funding appropriations for those years for which it is available from CRS data (FY2008, FY2009, and FY2011) along with funding authorizations for those years for which it was not (FY2010 and FY2012). The table lists funding from the 2009 Omnibus Appropriations Act separately from funding appropriated via the 2009 American Recovery and Reinvestment Act, which also occurred in FY2009. Although the appropriations data are not complete, Tables 2 and 3 make clear that many of the programs authorized by the America Competes Act were not funded at authorized levels during the Table 3 also demonstrates that some of the programs created by the 2007 ACA obtained their first significant appropriations through the 2009 American Recovery and Reinvestment Act. This is particularly true for ARPA-E, which had been authorized for $300 million FY2008 and was envisioned in the *Gathering Storm* report to receive as much as $1 billion in FY2009, but which was not funded in FY2008 and which received only $15 million in FY2009. Similarly, while the 2007 ACA created a number of new STEM education programs, few received funding in FY2008 or FY2009.

Part of the reason for the absence of funding in FY2008 is that the 2007 ACA was not passed until after the FY2008 budget had advanced through most of the appropriations process. In the wake of the 2008 financial crisis and subsequent recession, shifting priorities in Congress played a significant role in the years thereafter. Less than one percent of the funding authorized for new STEM programs at the Departments of Education or Energy by the 2007 ACA was appropriated by the of the FY2008 or FY2009 Omnibus Appropriations Acts. At the Department of Education, for example, the *Teachers for a Competitive Tomorrow (TCT) Baccalaureate Program* and the *TCT Master's Program* had been authorized to receive more than $100 million in appropriations in both FY2008 and FY2009, but each received only $1 million in each fiscal year. The Bush Administration's American Competitiveness Initiative and FY2008 budget requested $250 million for the *Math Now* program and the 2007 ACA authorized $95 million in funding for the program FY2008; however, $0 were appropriated for the program in FY2008 and FY2009. Whereas approximately $500 million had been authorized for Department of Education STEM programs in FY2008, only $4 million was appropriated in FY2008 and FY2009 combined. The new Department of Energy STEM programs created by the 2007 ACA were similarly unfunded, including the DOE's Early Career Awards for Science, Engineering, and Math Researchers; Protecting America's Competitive Edge (PACE) Graduate Fellowship Program, which had been authorized to receive more than $30 million. The ACA had not authorized new STEM programs at the National Science Foundation, which had, historically, distributed the majority of STEM education funds for higher education. However, the Act had authorized major expansions that did not materialize in the FY2008 and FY2009 budgets.

In addition to the STEM programs, a number of other key programs were unfunded (or underfunded relative to authorization levels) by the FY2008 and FY2009 budgets. These include the DOE's Discovery Science and Engineering Innovation Institutes.

The primary set of programs funded during FY2008 and FY2009 were those associated with the National Institute of Standards and the National Science Foundation. Programs funded at NIST included those historically central to the agency's mission, including the Scientific and Technical Research and Services (STRS) and Construction & Maintenance, and the Manufacturing Extension Partnership as well as the ACA-created Technology Innovation Program, which replaced the long-standing Advanced Technology Program. Indeed, NIST's programs were funded above ACA authorized levels and also received additional funding from the ARRA stimulus bill. The 2009 Omnibus Appropriations Act allocated less funding to the NSF and Department of Energy's Office of Science than had been authorized under the ACA. As a consequence of ARRA supplemental funding, each of these agencies ultimately received greater FY2009 funding than had been scheduled under the 2007 ACA.

IV. America COMPETES Reauthorization Act (2010)

4.1 ACRA2010: Overview of key provisions

The funding authorized by the 2007 America COMPETES Act covered only the years FY2008, FY2009, and FY2010. Thus, to continue the programs of the ACA2007, Congress either needed specific legislation aimed at continuing the 2007 ACA programs or it needed to consider funding for those programs along with other authorization packages. Whereas the ACA 2007 enjoyed relatively strong bi-partisan support as it evolved, the effort to reauthorize the 2007 Act was substantially more difficult and the debate more polarized. For example, the version of the reauthorization bill considered by the House of Representatives was voted upon and failed twice before it was passed on a third try in late May 2010.[23] The Senate passed an amended version late in December, leaving the House of Representatives to consider the amended bill before the lame duck 111th Congress adjourned. The House of Representatives passed the bill on the last day of the 111th Congress's session. Whereas the House bill had authorized spending for five years, the Senate version, and the ultimate Act authorized only three years of funding. The Senate bill also trimmed the funding authorization from the $85.6 billion authorized in the House measure to approximately $45 billion.[24]

The resulting 2010 ACRA retained the essential objectives of the 2007 Act, but did so with more modest expectations for funding. The discussion below highlights the Act's key features and describes their implementation:

(1) ***The Doubling Path:*** The retained the aim of doubling nominal science and technology funding for the physical sciences relative to the 2006 benchmark, but extended the timing of the expected doubling path from seven to ten years. The 2010 Act also retained the focus on increasing funding for NIST, the NSF, and Department of Energy's Office of Science. The FY2013 budgets

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[23] Mervis, Jeffrey (2010) "Third Time's a Charm for COMPETES Bill," *ScienceInsider*, May 28, 2010; http://news.sciencemag.org/scienceinsider/2010/05/third-times-a-charm-for-competes.html; accessed March 9, 2012.

[24] Reich, Eugenie Samuel (2010) "US Congress passes strategic science bill," *Nature*, Published online 22 December 2010, http://www.nature.com/news/2010/101222/full/news.2010.693.html, accessed March 9, 2012.

authorized for the NSF and DOE Office of Science by the 2010 ACRA were approximately $8.3 billion and $6.0 billion, amounts that represented only a few percentage point increase relative to the FY2010 budgets authorized by the 2007 COMPETES Act. The much-smaller NIST budget FY2013 was authorized for a 15 percent increase relative to the ACA 2007 FY2010 amount and was scheduled to increase to $676 billion by FY2013.

(2) ***STEM Education:*** Like the original 2007 Act, the 2010 ACRA addressed a number of STEM education issues. Specifically, the Act (a) charged the OSTP with a leadership role in coordinating federal STEM education efforts, (b) directed agencies to undertake efforts related to STEM education initiatives, particularly related to underrepresented minorities, and (c) authorized funding for STEM education programs. Section 101 of the Act required the OSTP to coordinate STEM education under the National Science and Technology Council (NSTC) and Congress requested both a five-year plan and an annual report on STEM education. Efforts at ensuring additional educational opportunities for underrepresented minorities were included in the Titles of the 2010 Act for a number of agencies, including, for example, the National Oceanic and Atmospheric Administration (Section 302). Further, the NSF was instructed to support grants for research and STEM education at historically black colleges, tribal colleges, and Hispanic-serving institutions of higher education. The 2010 Act consolidated funding in a smaller number of programs and eliminated a series of programs that had been authorized by the 2007 ACA but not funded subsequently. The 2010 Act concentrated STEM education funding to a greater degree in the NSF and a lesser degree in the Departments of Energy and Education and authorized less funding for STEM education than the 2007 Act. The ACRA did authorize $10 million in funding to support individuals pursing higher education in STEM fields simultaneously with teacher certification.

(3) ***ARPA-E***: The Advanced Research Projects Agency – Energy at the Department of Energy was extended by the 2010 Act. $300 million was authorized for funding the agency in fiscal year

FY2011; this authorization was increased by $6 million in FY2012 and another $6 million in FY2013.

(4) ***Prizes****:* One notable addition to the America COMPETES framework was the stipulation that, "each head of an agency, or the heads of multiple agencies in cooperation, may carry out a program to award prizes competitively to stimulate innovation that has the potential to advance the mission of the respective agency." This idea had been advanced in the Obama Administration's 2009 *Strategy for American Innovation*. Although prizes for innovations are not new, either in theory or in practice, prizes have received increasing attention from academics, policymakers, and businesses over the past decade.[25] The 2010 ACRA was broke new ground in specifying that innovation inducement prizes could be offered by all federal agencies, subject to the discretion of each agency director. The Act does not place specific limitations on the amounts of prizes. It does, however, specified that prizes could not be offered unless sufficient federal funds had already been appropriated or if private funds had been committed in writing.[26] The Act also requires that Congress be notified in writing 30 days before the approval of any prize greater than $50,000 and that Agency directors must specifically approve funding for any prize in excess of $1,000,000.

(5) ***Other programs:*** In addition to its support for the programs identified above, the 2010 ACRA established a number of new federal programs. The Act established the Regional Innovation Program at the Department of Commerce, including a component aimed at supporting regional innovation by providing loan guarantees for science and research parks. Another program created

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[25] See Gallini, Nancy and Suzanne Scotchmer, (2002) *Intellectual Property: When Is It the Best Incentive System*, Cambridge: MA: Thomas Kalil (2006) "Prizes for technological innovation," Discussion Paper 2006-08, The Hamilton Project, The Brookings Institution; MIT Press.; Michael Kremer and Heidi Williams (2010) "Incentivizing innovation: Adding to the toolkit," in Josh Lerner and Scott Stern, eds., *Innovation Policy and the Economy*, Volume 10, University of Chicago Press, 1-17; Brunt, Liam, Josh Lerner, and Tom Nicholas (2012) "Inducement Prizes and Innovation," *Journal of Industrial Economics,* forthcoming; Kevin J. Boudreau , Nicola Lacetera, & Karim Lakhani (2011) "Incentives and Problem Uncertainty in Innovation Contests: An Empirical Analysis," *Management Science*, 57(5), 843-863; and Heidi Williams (2012) "Incentives, prizes, and innovation, MIT working paper. Note that many of these papers build on Brian Wright (1983) "The economics of invention incentives: Patents, prizes, and research contracts," *American Economic Review*, 73(4), 691-707.

[26] Private funding of federal prizes, including matching funding, was specifically enabled the by Act; however, the Act was careful to note that private entities were not entitled to obtain consideration in exchange for inducement prize funding. (P.L. 111-358, Section 105).

in the Department of Commerce offered federal loan guarantees for small- and medium-sized enterprises engaged in the manufacture of innovative technologies. The Act also included the NIST Grants for Energy Efficiency, New Job Opportunities, and Business Solutions Act of 2010 (included in the 2010 ACRA as the "NIST GREEN JOBS Act of 2010"), which enabled projects related to energy efficiency to be funded under the Hollings Manufacturing Extension Partnership (MEP) Program.

4.2 ACRA 2010 Funding & Implementation

As was case with the 2007 America COMPETES Act and FY2008 appropriations, the 2010 America COMPETES Reauthorization Act was not signed into law until after its fiscal year appropriations process, FY2011, had been begun. Moreover, the 2010 ACRA was passed during a period of intense Congressional debate about the federal budget, the budget deficit, and the extent of federal debt. In the wake of the 2008 financial crisis, ensuring recession, and shift from a Democratic majority to a Republican majority in the House of Representatives in 2010, partisanship was on the rise in the 111th Congress. In addition to the general trend in partisanship, the ability to agree on science and technology policy in the House Committee on Science, Space, and Technology, the committee responsible for both the ACA2007 and ACRA2010 legislation, was made more difficult by key retirements.[27] Bart Gordon (D-TN), sponsor of both the ACA2007 and ACRA 2010 retired in 2010, as did physicist Vernon Ehlers (R–MI), ranking member of the Subcommittee on Research and Science Education.

As a consequence of the timing of the ACRA's passing and the prevailing economic and political circumstances, few of the programs authorized in the 2010 were funded by FY2011 appropriations. For example, the Teachers for a Competitive Tomorrow program, which had been authorized for more than $275 million ($151.20 million for the Baccalaureate program and another $125 million for the Master's program) received $0 in FY2011 appropriations, although it had received approximately $2 million in

[27] Julie Palakovich Carr (2010) "Major Changes in Congress May Mean Major Changes for Science Policy," *BioScience*, 60(10), 786.

FY2010 and $2 million in FY2012. Table 4 lists programs authorized for funding by the 2010 ACRA for which there were no specific appropriations were funded in FY2012.

Not all ACRA 2010 programs were unfunded or underfunded relative to authorizations, however. The Manufacturing Extension Program (MEP), for example, received 3.0% ($128.4 million) more funding in FY2011 than it had in FY2010 ($124.7 million). ARPA-E received $0 in FY2010 appropriations. The program received $179.6 million in FY2011 appropriations, marking the first time that the ACA 2007 program had received appropriations outside of the 2009 ARRA Act. ARPA-E's funding was increased to an estimated $275 million in FY2012.

V. A Half Decade of The America COMPETES Act: A Review

Although the America COMPETES Act was introduced in 2007 with bipartisan support, fanfare from the business community, and plaudits from the science policy community, the tangible outputs of the Act and its subsequent Reauthorization appear limited. As the United States Congress engages deliberations over FY2013 appropriations, the final fiscal year in which the ACRA authorizes science and technology funding, it remains unclear whether the vision for the ACA outlined in the Gathering Storm report, the Bush Administration's American Competitiveness Initiative, and subsequently embraced by the Obama Administration's Innovation Strategy, will be realized. This sections reviews the America COMPETES Act's signature initiatives, reviews their implementation to date, and assesses the likely impact of those initiatives on U.S. science and technology outputs and associated economic measures.

(1) **The Doubling Path**: One of the signature initiatives of the ACA 2007 and ACRA 2010 and one of the bolder visions of its supporters was the aim of doubling federal funding for the physical sciences, in nominal terms, relative to the FY2006 base year. Initially targeted to be achieved in ten years, the aspirations for the doubling path were revised with the implementation of the 2007 Act and have been subsequently loosened since. Figure 1 tracks the potential doubling of federal funding for science and technology in the agencies targeted for doubling, the National Science

Foundation, Department of Energy's Office of Science, and the National Institute for Standards and Technology's Core Research and Construction. The figure traces (in grey) paths for doubling federal funding over seven years, ten years, eleven years, and fifteen years. It also identifies (in color) the paths specified by the COMPETES Acts, presidential budget requests, OMB projections, and actual spending. The Bush Administration funding requests (FY2007-FY2009, burgundy line) follow the ten year doubling path outlined in the American Competitiveness Initiative. Expectations for the doubling path were raised by the 2007 ACA (FY2008-FY2010, orange line), which were to follow the seven-year doubling target. Actual appropriations (green line) in FY2007 and FY2008 followed a fifteen-year doubling path, but were boosted in FY2009 and FY2010, reaching a trajectory for eleven-year doubling, even without including FY2009 ARRA funding. The Obama Administration budget requests for FY2010, FY2011, and FY2011 (blue line) followed the eleven-year doubling trajectory, as did the authorizations of the 2010 America COMPETES Reauthorization Act. However, actual appropriations in FY2011 (and subsequently in FY2012, not pictured) departed significantly from the doubling path. The Obama Administration's FY2013 budget requests an increase in funding for the doubling agencies of 4.1%. Annual 10% per year increases would be required to ensure a seven-year path and 7% per year increases would be required to sustain a ten-year doubling path; were the Administration's FY2013 request of a 4.1% increase in funding for these agencies and programs, the time period required to double nominal federal funding for the physical sciences relative to the FY2006 base would be approximately eighteen years.[28] Considering the FY2011-FY2012 trajectory, the Obama Administration's FY2013 budget request, and Office of Management and Budget projections for FY2013 and FY2016, it seems fair to conclude that the effort to double federal funding for the physical sciences has been put on hold, if not abandoned.

[28] For additional details, see Heather B. Gonzalez, "America COMPETES 2010 and the FY2013 Budget," CRS42430, 20-March-2012.

(2) STEM Education: The second effort most-closely associated with the America COMPETES Acts was the aim of improving U.S. support for STEM education. The 2007 ACA and 2010 ACRA authorized the creation and funding of numerous programs devoted to improving STEM teacher training, increasing the number of STEM-trained graduates, and creating opportunities for underrepresented minorities to pursue STEM education. In the time since the 2007 ACA, however, few of these new initiatives have received regular funding. For example, the Teachers for a Competitive Tomorrow: Baccalaureate Degrees and Master's Degrees programs, which were authorized by both COMPETES Acts, received annual average funding of approximately $1 million, although each had been authorized to receive more than $100 million in each fiscal year. Many programs, including the Department of Energy's Experiential-Based Learning Opportunities; Early Career Awards for Science, Engineering, and Mathematics Researchers; Discovery Science and Engineering Innovation Institutes; Protecting America's Competitive Edge (PACE) Graduate Fellowship Program; and Distinguished Scientist Program, each of which was authorized for between $10 million and $30 million in funding in FY2010, remained unfunded. Although fewer STEM education programs were created by the 2010 ACRA 2010, many of these also went unfunded in subsequent years, including the NSF's STEM-Training Grant Program, which had been authorized for approximately $10 million in annual funding, and the Department of Education's Alignment of Education Programs, for which approximately $125 million had been authorized annually. The winnowing of STEM education programs authorized by the COMPETES Acts did not mean that STEM education efforts in the United States ceased from FY2008-FY2012, however. Federal funding for STEM education occurs principally through the National Science Foundation's Education and Human Resources (E&HR) program, which received an estimated $829.00 million in FY2012, and whose budget had been increasing between 3% and 10% between FY2008 and FY2011 before decreasing (in estimation) by nearly 4% between FY2011 and FY2012. Although STEM education continues to be a focus of federal policy discussion and carries nominal support with the public, Congress, and President, the overall impact of the America COMPETES Act on STEM education funding and program development has not been consequential to date.

(3) ARPA-E: The Advanced Research Projects Agency-Energy (ARPA-E) at the Department of Energy constitutes a third component that was embraced by both COMPETES Acts, the *Gathering Storm Report*, and the American Competitiveness Initiative. The agency was created in the 2007. It received $15 million in the FY2009 budget, but did not receive substantial funding until the 2009 ARRA appropriated $400 million, from which it could begin to solicit research proposals and disperse funding. ARPA-E's did not receive appropriations in FY2010, although it did receive nearly $180 million in FY2011 and an estimated $275 million in FY2012. These funding levels have enabled ARPA-E to award $521.7 million in grants to approximately 180 awardees as of March 2012. The agency issued a call for $150 million in additional proposals in March 2012.[29] In addition to its research funding, the Agency has held three Energy Innovation Summits that showcase research by ARPA-E awardees, applicants, and other contributors. Although the overall level of funding for ARPA-E has not reached the levels envisioned by *The Gathering Storm* and is substantially lower than the DARPA annual budget ($3.2 billion), ARPA-E can be considered as an outcome associated with the COMPETES Acts, particularly when the total estimated annual U.S. investment in energy-related R&D is approximately $5.1 billion.[30] It is currently too early to assess the impact of ARPA-E on energy innovation; however, studies like those conducted by Erica Fuchs of DARPA[31] could be insightful and could set the stage for further work.

(4) Prizes: Federal agencies were given latitude to develop inducement prizes under the 2010 COMPETES Reauthorization Act. Numerous agencies, including the Department of Defense,

29 ARPA-E (2012) "ARPA-E issues open call for transformational energy technologies," March 2, 2012, http://arpa-e.energy.gov/media/news/tabid/83/vw/1/itemid/49/Default.aspx; accessed March 2012.

30 President's Council of Advisors on Science and Technology (2010) "Report to the President on accelerating the pace of change in energy technologies through an integrated federal energy policy," November 10, 2010; http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-energy-tech-report.pdf; accessed January 2012.

31 Erica R.H. Fuchs (2010) "Rethinking the role of the state in technology development: DARPA and the case for embedded network governance," *Research Policy*, 39(9), 1133-1147.

Department of Energy, Environmental Protection Agency, and NASA had sponsored prizes prior to the ACRA, including a number of prizes of value greater than $2 million.[32] This approval has led to the establishment of a clearinghouse for federal prize programs, challenge.gov, which posts prize descriptions, eligibility conditions, submissions procedures, timelines, and rules. Federal prize programs, particularly those at NASA, have already become the subject of academic study.[33] The extent of federal prize programs continues to grow and it is too soon to measure the overall impact of such programs on innovation. It is possible that success with federal prizes may contribute to momentum for yet more ambitious attempts at inducements, such as those described by Kremer and colleagues.[34]

Compared to the grand expectations associated with the development and introduction of the America COMPETES Acts, the accomplishments to date appear relatively modest. The financial crisis, associated recession, and their political impact exerted a substantial impact on the implementation of ACA programs. Indeed, as Figure 2 shows, the U.S total real federal investment in science and technology agencies has not appreciated in the past decade. Thus, the broader questions regarding the impact of the globalization of science and technology on U.S. innovation, competitiveness, employment, and overall social welfare loom as especially salient in the wake of the ACA's limited implementation. That said, with a few exceptions,[35] academic guidance is also somewhat limited regarding what might have occurred had the ACA policies in programs been implemented as authorized.

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[32] Deborah Stine (2009) "Federally-Funded Innovation Inducement Prizes," Congressional Research Services Report, R40677, June 29, 2009.

[33] See, in particular, the work of Karim Lakhani and colleagues, including Kevin J. Boudreau, Nicola Lacetera, & Karim Lakhani (2011) "Incentives and Problem Uncertainty in Innovation Contests: An Empirical Analysis," *Management Science*, 57(5), 843-863.

[34] Michael Kremer and Heidi Williams (2010) "Incentivizing innovation: Adding to the toolkit," in Josh Lerner and Scott Stern, eds., *Innovation Policy and the Economy*, Volume 10, University of Chicago Press, 1-17.

[35] Richard Freeman and John van Reenen (2009) "What if Congress Doubled R&D Spending on the Physical Sciences?" in Josh Lerner and Scott Stern, eds., *Innovation Policy and the Economy*, Volume 9, University of Chicago Press, 1-38.

Table 1. Summary of Recommendations of National Academies Report, *The Gathering Storm*

- **Recommendation A:** Increase America's talent pool by vastly improving K–12 science and mathematics education.
  - **Action A-1:** Annually recruit 10,000 science and mathematics teachers by awarding 4-year scholarships and thereby educating 10 million minds
  - **Action A-2:** Strengthen the skills of 250,000 teachers through training and education programs at summer institutes, in master's programs, and in Advanced Placement (AP) and International Baccalaureate (IB) training programs
  - **Action A-3:** Enlarge the pipeline of students who are prepared to enter college and graduate with a degree in science, engineering, or mathematics by increasing the number of students who pass AP and IB science and mathematics courses.
- **Recommendation B:** Sustain and strengthen the nation's traditional commitment to long-term basic research that has the potential to be transfor mational to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.
  - **Action B-1:** Increase the federal investment in long-term basic research by 10% each year over the next 7 years through reallocation of existing funds or, if necessary, through the investment of new funds.
  - **Action B-2:** Provide new research grants of $500,000 each annually, payable over 5 years, to 200 of the nation's most outstanding early-career researchers.
  - **Action B-3:** Institute a National Coordination Office for Advanced Research Instrumentation and Facilities to manage a fund of $500 million in incremental funds per year … to ensure that universities and government laboratories create and maintain the facilities, instrumentation, and equipment needed for leading-edge scientific discovery and technological development.
  - **Action B-4:** Allocate at least 8% of the budgets of federal research agencies to discretionary funding.
  - **Action B-5:** Create in the Department of Energy an organization like the Defense Advanced Research Projects Agency (DARPA) called the Advanced Research Projects Agency-Energy (ARPA-E).
  - **Action B-6:** Institute a Presidential Innovation Award to stimulate scientific and engineering advances in the national interest.
- **Recommendation C:** Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world.
  - **Action C-1:** Increase the number and proportion of US citizens who earn bachelor's degrees in the physical sciences, the life sciences, engineering, and mathematics by providing 25,000 new 4-year competitive undergraduate scholarships each year to US citizens attending US institutions.
  - **Action C-2:** Increase the number of US citizens pursuing graduate study in "areas of national need" by funding 5,000 new graduate fellowships each year.
  - **Action C-3:** Provide a federal tax credit to encourage employers to make continuing education available (either internally or through colleges and universities) to practicing scientists and engineers.
  - **Action C-4:** Continue to improve visa processing for international students and scholars
  - **Action C-5:** Provide a 1-year automatic visa extension to international students who receive doctorates or the equivalent in science, technology, engineering, mathematics, or other fields of national need at qualified US institutions to remain in the United States to seek employment. If these students are offered jobs by US-based employers and pass a security screening test, they should be provided automatic work permits and expedited residence status.
  - **Action C-6:** Institute a new skills-based, preferential immigration option.
  - **Action C-7:** Reform the current system of "deemed exports
- **Recommendation D:** Ensure that the United States is the premier place in the world to innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs based on innovation by such actions as modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access.
  - **Action D-1:** Enhance intellectual-property protection for the 21st century global economy
  - **Action D-2:** Enact a stronger research and development tax credit to encourage private investment in innovation.
  - **Action D-3:** Provide tax incentives for US-based innovation.
  - **Action D-4:** Ensure ubiquitous broadband Internet access.

Table 2 – Overview of FY2009 Funding Authorizations for 2007 America COMPETES Act Programs

Funding includes both FY2009 Omnibus Appropriations Act and American Recovery and Reinvestment Act	
Programs Presumably Not Funded in FY2009	**Programs Funded at Authorized Levels in FY2009**
Department of Energy • Pilot Program of Grants to Specialty Schools for Science and Mathematics • Experiential Based Learning Opportunities • Summer Institutes • National Energy Education Development • Nuclear Science Talent Expansion Program • Hydrocarbon Systems Science Talent Expansion Program • Early Career Awards for Science, Engineering, and Mathematics Researchers • Discovery Science and Engineering Innovation Institutes • Protecting America's Competitive Edge Graduate Fellowship Program • Distinguished Scientist Program **Department of Education** • Advanced Placement & International Baccalaureate Program • Math Now • Summer Term Education Program • Math Skills for Secondary Skill Students • Advancing America Through Foreign Language Partnership Program • Mathematics and Science Partnership Bonus Grants **National Science Foundation** • Laboratory Science Pilot Program	**Department of Energy** • Office of Science **National Science Foundation** • Research & Related Activities • Major Research Instrumentation • Professional Science Master's Degree Program • Robert Noyce Teacher Scholarship Program • Graduate Research Fellowship Program • Major Research Equipment and Facilities Construction **NIST** • Scientific & Technical Research and Services • Construction & Maintenance

Source: Deborah D. Stine (2009) "America COMPETES Act: Programs, Funding, and Selected Issues," Congressional Research Service, RL3428, April 17, 2009.

Table 3. Programs & Funding Status of America COMPETES Act (2007 & 2010) Programs (millions of dollars)

Programs with Specific Authorized Budgets in the 2007 America COMPETES Act					
Program	**FY2008 Appropriated**	**FY2009 Appropriated**	**FY2009 ARRA**	**FY2010 Estimated**	***FY2010 Authorized***
Department of Energy					
Office of Science	4,035.60	4,757.60	1,600.00	4,903.70	*5,814.00*
Advanced Research Projects Agency— Energy*	~	15.00	400.00	0.00	*as needed*
Department of Education					
Teachers for a Competitive Tomorrow: Baccalaureate*	0.98	1.10	^	1.10	*151.20*
Teachers for a Competitive Tomorrow: Master's*	0.98	1.10	^	1.10	*125.00*
Department of Commerce					
National Institute of Standards and Technology					
Scientific & Technical Research and Services (STRS)	440.50	472.00	222.00	515.00	*548.80*
Construction & Maintenance	160.50	172.00	360.00	147.00	*49.70*
Technology Innovation Partnership (TIP)*	65.20	65.00		69.60	*140.50*
Manufacturing Extension Partnership (MEP)				124.70	
National Science Foundation	6,127.50	6,490.00	3,002.00	6,872.50	*8,132.00*
Research and Related Activities (R&RA)	4,844.00	2,183.00	2,500.00	5,617.90	*6,401.00*
Major Research Instrumentation (MRI)	^	^	300.00	^	*131.70*
Exp Prog to Stimulate Competitive Research	120.00	133.00	^	147.10	*147.80*
Education and Human Resources (EHR)	765.50	845.30	100.00	872.80	*11,040.00*
Math & Sci Ed Partnership (MSP)	^	61.00	25.00	58.20	*123.20*
Robert Noyce Teacher Scholarship Program	55.00	55.00	60.00	55.00	*140.50*
Graduate Research Fellowship/EHR (GRF)	^	107.00	^	102.60	*119.00*
Major Research Equipment & Facilities Construction	220.70	152.00	400.00	117.30	*280.00*
Agency Operations and Award Management	281.80	294.00	^	300.00	*329.50*
National Science Board	4.00	4.00	^	4.50	*4.30*
Inspector General	11.40	12.00	2.00	14.00	*13.20*

Programs with Specific Authorized Budgets in the 2010 Act				
Programs	**FY2011 Appropriated**	**FY2012 Estimated**	***FY2012 Authorized***	***FY2013 Authorized***
Department of Energy				
Office of Science	4,842.70	4,873.60	*5,614.00*	*6,000.70*
Advanced Research Projects Agency - Energy	179.60	275.00	*306.00*	*312.00*
Department of Education				
Teachers for a Competitive Tomorrow – BA	^	^	*2.00*	*2.00*
Teachers for a Competitive Tomorrow – MA	^	^	*2.00*	*2.00*
Department of Commerce				
National Institute of Standards and Technology	878.60	750.8		*1039.7*
Scientific & Technical Research & Services	507.00	567.00	*661.10*	*676.70*
Construction of Research Facilities	69.90	55.40	*84.90*	*121.30*
Industrial Technology Services	173.30	224.80	*224.80*	
Technology Innovation Partnership (TIP)*		eliminated	*eliminated*	*eliminated*
Manufacturing Extension Partnership (MEP)	128.40	128.40	*155.10*	*165.10*
NIST Green Jobs Act of 2010*		^		*7.00*
Dept of Commerce (other than NIST)				
Loan Guarantees for Innov Tech in Mfg*		5.00		*20.00*
Loan Guarantees for Science Park Infrastructure*		5.00		*7.00*
Regional Innovation Program*		^		
National Science Foundation	6,859.90	7,033.60	*7,800.00*	*8,300.00*
Research & Related Activities	5,563.90	5,689.00	*6,234.30*	*6,637.80*
Education & Human Resources	861.00	829.00	*979.00*	*1,041.80*
Major Research Equip & Facilities Construction	117.10	197.10	*225.50*	*236.80*
Agency Operations & Award Management	299.40	299.40	*341.70*	*363.70*
National Science Board	4.50	4.40	*4.80*	*4.90*
Office of the Inspector General	14.00	14.70	*14.70*	*15.00*

Programs without entries for particular Fiscal Years are not mentioned in the documents summarizing funding for those programs in those years.

"^" = not included" or "not defined"; these programs are specifically mentioned in the source documents as being not included in authorization or appropriation acts.

** = new program (note: The Technology Innovation Partnership was a new program that replaced the old, "Advanced Technology Partnership")*

Appropriations & FY2012 Authorization data = Table 1, "America COMPETES 2010," H. B. Gonzalez, CRS-R41906, 11-22-2011; FY2012 Estimated & FY2013 Authorized data = "America COMPETES 2010 and the FY2013 Budget," Heather B. Gonzalez, CRS42430, 20-March-2012.

Table 4: Programs authorized by the 2010 ACRA for which funding was unspecified in FY2011-FY2012*

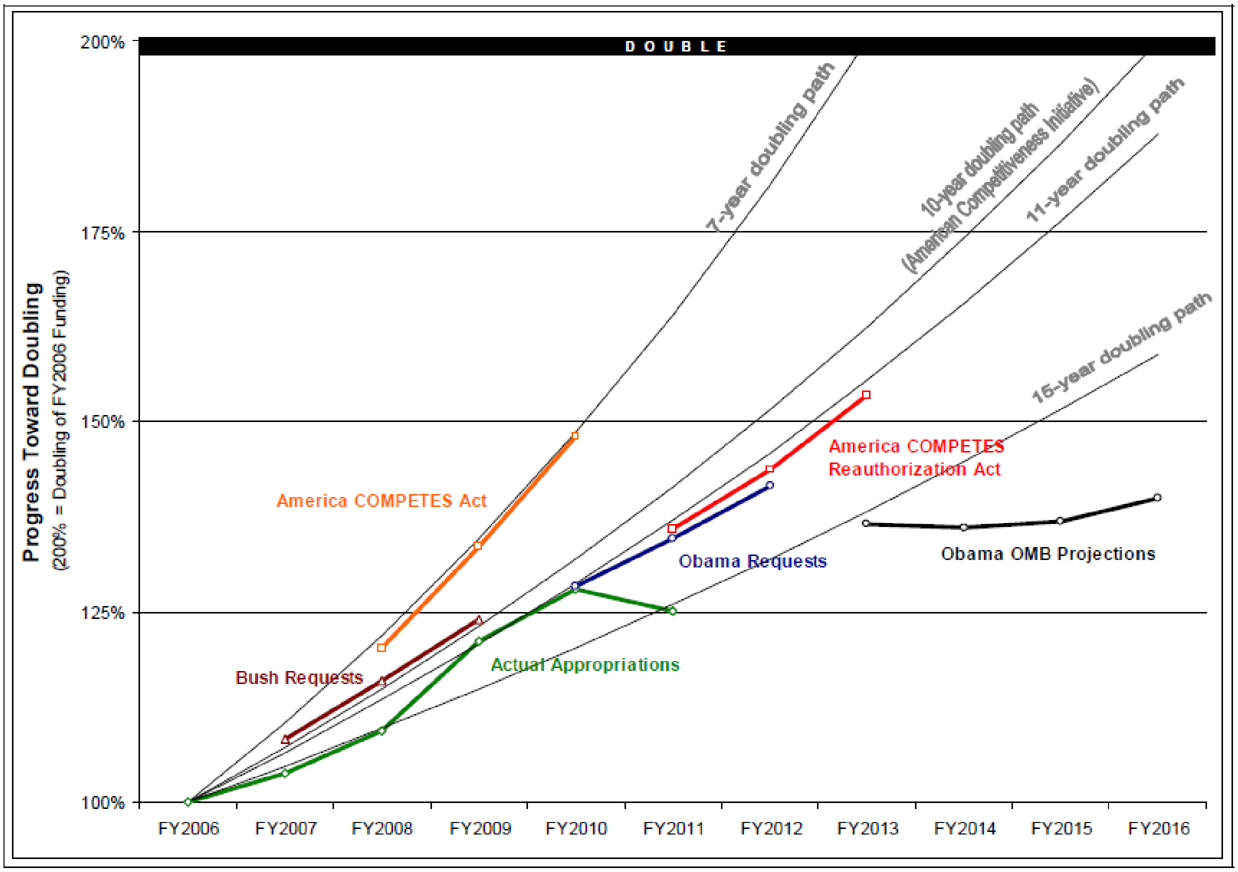
Department/Program	Section of ACRA 2010	FY2013 Authorization ($ million)
Department of Education		
Teachers for a Competitive Tomorrow - BA	1003	**2.0**
Teachers for a Competitive Tomorrow - MA	1003	**2.0**
Advanced Placement and International Baccalaureate Programs	1003	**75**
Alignment of Education Programs)	1003	**120.0**
Department of Energy		
Summer Institutes	901	**25.0**
Nuclear Science Program Expansion Grants for Institutions of Higher Education	902	**10.4**
Nuclear Science Competitiveness Grants for Institutions of Higher Education	902	**8.8**
Hydrocarbon Systems Science Talent Program Expansion Grants	902	**10.1**
Early Career Awards	902	**25.0**
Protecting America's Competitive Edge (PACE) Graduate Fellowship Program	902	**21.9**
Distinguished Scientist Program	902	**33.0**
Department of Commerce		
Regional Innovation Program	603	**100.0**
NIST		
Baldrige Performance Excellence Program		**10.6**
NIST Green JOBS Act of 2010	703	**7.0**
National Science Foundation		
STEM-Training Grant Program	556	**10.0**

* These programs can be presumed to be unfunded by the 2010 ACRA, although they may be funded through other acts or fungible sources of agency funding.

Source: "America COMPETES 2010 and the FY2013 Budget," Heather B. Gonzalez, CRS42430, 20-March-2012.

Figure 1: The Doubling Path in Research Funding for the Physical Sciences

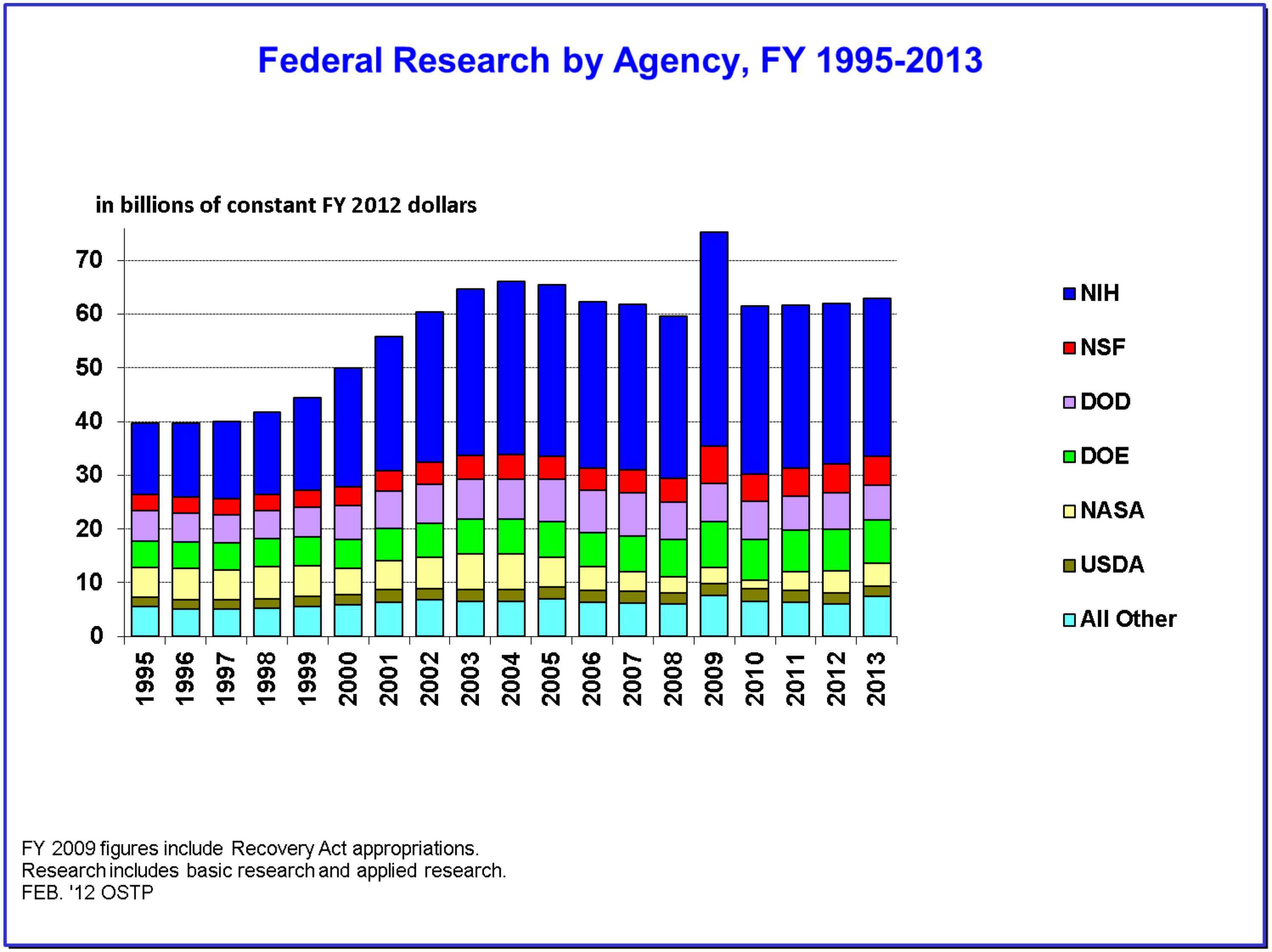
Figure tracks potential doubling of federal funding for science and technology, including funding for the NSF, DOE Office of Science, and NIST Core Research and Construction relative to FY2006 appropriations levels



Notes: (1) "Obama OMB Projections" represent the projections by the Office of Management and Budget for FY2013-FY2016, including supplemental information in President Obama's FY2012 budget request and (2) Funds provided by the FY2009 American Recovery and Reinvestment Act (ARRA) are not included in the graphic.

Source for figure & notes: "America COMPETES 2010," H. B. Gonzalez, CRS-R41906, 11-22-2011, citing John F. Sargent, Jr, Specialist in Science & Technology Policy, Congressional Research Service.

Figure 2: Federal Research Funding, by Agency, in constant FY2012 $billions



Notes: FY2012 data estimated, FY2013 based on Presidential Budget Request.
Source: Office of Science & Technology Policy (2012)