The National Nanotechnology Initiative: Overview, Reauthorization, and Appropriations Issues

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May 13, 2010

Congressional Research Service
7-5700
www.crs.gov
RL34401

CRS Report for Congress
Prepared for Members and Committees of Congress

Summary

Nanotechnology—a term encompassing the science, engineering, and applications of submicron materials—involves the harnessing of unique physical, chemical, and biological properties of nanoscale substances in fundamentally new and useful ways. The economic and societal promise of nanotechnology has led to substantial and sustained investments by governments and companies around the world. In 2000, the United States launched the world's first national nanotechnology program. From FY2001 through FY2010, the federal government invested approximately $12.4 billion in nanoscale science, engineering, and technology through the U.S. National Nanotechnology Initiative (NNI). U.S. companies and state governments have invested billions more. President Obama has requested an additional $1.8 billion in NNI funding for FY2011. As a result of this focus and these investments, the United States has, in the view of many experts, emerged as a global leader in nanotechnology. However, the competition for global leadership in nanotechnology is intensifying as countries and companies around the world increase their investments.

Nanotechnology's complexity and intricacies, early stage of development (with commercial pay-off possibly years away for many potential applications), and broad scope of potential applications engender a wide range of public policy issues. Maintaining U.S. technological and commercial leadership in nanotechnology poses a variety of technical and policy challenges, including development of technologies that will enable commercial scale manufacturing of nanotechnology materials and products; environmental, health, and safety (EHS) concerns; and maintenance of public confidence in its safety.

Congress established programs, assigned responsibilities, and initiated research and development (R&D) related to these issues in the 21st Century Nanotechnology Research and Development Act of 2003 (P.L. 108-153). While many provisions of this act have no sunset provision, FY2008 was the last year of agency authorizations included in the act. Legislation to amend and reauthorize the act was introduced in the House (H.R. 5940, 110th Congress) and the Senate (S. 3274, 110th Congress) in the 110th Congress. Both bills were titled the National Nanotechnology Initiative Amendments Act of 2008. The House passed H.R. 5940 by a vote of 407-6; the Senate did not act on S. 3274. In January 2009, H.R. 554, the National Nanotechnology Initiative Amendments Act of 2009, was introduced in the 111th Congress. The act contains essentially the same provisions as H.R. 5940 (110th Congress). In February 2009, the House passed the bill by voice vote under a suspension of the rules. The bill was referred to the Senate Committee on Commerce, Science, and Transportation; no further action has been taken. On May 7, 2010, the House Committee on Science and Technology reported the America COMPETES Reauthorization Act of 2010 (H.R. 5116) which includes, as Title I, Subtitle A, the National Nanotechnology Initiative Amendments Act of 2010. Provisions of this subtitle are nearly identical to the provisions of H.R. 554.

Proponents of the NNI assert that nanotechnology is one of the most important emerging and enabling technologies and that U.S. competitiveness, technological leadership, national security, and societal interests require an aggressive approach to the development and commercialization of nanotechnology. Critics of the NNI voice concerns that reflect disparate underlying beliefs. Some critics assert that the government is not doing enough to move technology from the laboratory into the marketplace. Others argue that the magnitude of the public investment may skew what should be market-based decisions in research, development, and commercialization. Still other critics say that the inherent risks of nanotechnology are not being addressed in a timely or effective manner.

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Introduction

Nanotechnology has been an issue of interest to Congress for a number of years, coming into focus in 2000 with the launch of the U.S. National Nanotechnology Initiative (NNI) by President Clinton in his FY2001 budget request to Congress. From FY2001 through FY2010, Congress appropriated approximately $12.4 billion for nanotechnology research and development (R&D).[1] These efforts have been directed at advancing understanding and control of matter at the nanoscale,[2] where the physical, chemical, and biological properties of materials differ in fundamental and useful ways from the properties of individual atoms or bulk matter.[3]

Nanotechnology: A Description

The term "nanotechnology" is often used as an all-encompassing term for nanoscale science, engineering, and technology. Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, the size-scale between individual atoms and bulk materials, where unique phenomena enable novel applications. A nanometer is one-billionth of a meter, or about the width of 10 hydrogen atoms arranged side-by-side in a line. Nanotechnology involves imaging, measuring, modeling, and manipulating matter at this size-scale.

At the nanoscale, the physical, chemical, and biological properties of materials can differ in fundamental and useful ways from the properties of individual atoms and molecules or bulk matter. Nanotechnology R&D is directed toward understanding and creating improved materials, devices, and systems that exploit these new properties.

Physicist Richard Feynman's remarks at the 1959 annual meeting of the American Physical Society are often cited as the first articulation of and vision for nanotechnology. Though he did not use the term nanotechnology in this speech, he spoke of controlling matter at the nanoscale and creating atomic-level machines, positing some of the applications that doing so might enable.

Source: *The National Nanotechnology Initiative Strategic Plan, 2004,* Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, December 2004.

The development and application of nanotechnology—more fully explained below—across a wide array of products and industries holds the potential for significant economic and societal benefits. To capture these benefits, the United States will have to effectively address a variety of technical and policy challenges that stand as potential barriers to commercialization, including environmental, health, and safety (EHS) concerns and their implications for workplace, environmental, food, and drug regulations; development of standards, reference materials, and consistent nomenclature; development of new measurement methods and tools; effective technology transfer to the private sector; protection of intellectual property; availability, affordability, and patience of investment capital; ethical, legal, and societal concerns; public understanding, support, and acceptance; and development of a world-class scientific and technical nanotechnology workforce.

This report provides an overview of nanotechnology, the National Nanotechnology Initiative, possible reauthorization of the 21st Century Nanotechnology Research and Development Act of 2003 (P.L. 108-153), and appropriations issues.

[1] President Obama requested $1.6 billion in nanotechnology R&D funding for FY2010. Although Congress has passed all of the regular appropriations acts, the precise amount provided for FY2010 is currently under evaluation by the agencies and the White House Office of Management and Budget and will likely be published with the President's FY2011 budget request in February 2010.

[2] In the context of the NNI and nanotechnology, the nanoscale refers to a dimension of 1 to 100 nanometers (see box on this page).

[3] While extensive R&D has been, and continues to be, conducted to understand and harness the properties of individual atoms, this is not the domain of nanotechnology.

Overview

The economic and societal promise of nanotechnology has led to involvement and investments by governments and companies around the world. In 2000, the United States became the first nation to establish a formal, national initiative to advance nanoscale science, engineering, and technology—the National Nanotechnology Initiative. Since then, Congress has appropriated approximately $12.4 billion in nanoscale science, engineering, and technology through the NNI. U.S. companies and state governments have invested billions more.

As a result of this focus and these investments, the United States has emerged as a global leader in nanotechnology. However, the competition for global leadership is intensifying as foreign investments in nanoscale science, engineering, and technology increase. Other nations have followed the U.S. lead and established their own national nanotechnology programs, each with varying degrees of investment, foci, and support for industrial applications and commercialization. Today, almost every nation that supports R&D has a national-level nanotechnology program.

Global public investments in nanotechnology in 2009 alone were estimated to be $9.8 billion, with cumulative global public investments through 2009 reaching approximately $50 billion.[4] In 2005, an assessment of the NNI by the President's Council of Advisors on Science and Technology (PCAST) reported that the United States leads all other nations in public investments in nanotechnology R&D, accounting for about a quarter of global annual public investments.[5] An April 2009 report by Cientifica, a privately-held nanotechnology business analysis and consulting firm, states that the U.S. share of global public nanotechnology funding has fallen to 19% in 2009 from 31% in 2004, calculated on a currency exchange rate basis, behind Russia (23%) and the European Union (EU) States (collectively, 27%).[6] The situation appears even less favorable when the share of investment is calculated on a purchasing power parity (PPP) basis (which takes into account the price of goods and services in each nation). Using a PPP approach, Cientifica concluded in its report that the U.S. share of global public nanotechnology investments is 16%, less than Russia (25%), and the EU States (27%), and the same as China (16%).[7]

Global investments in nanotechnology already have begun to yield economic benefits as products incorporating nanotechnology enter the marketplace. These products are estimated to have produced $147 billion in revenues in 2007 (including $59 billion in the United States, $47 billion in Europe, $31 billion in Asia/Pacific, and $9 billion in other nations).[8] By tapping the unique properties that emerge at the nanoscale, proponents maintain that nanotechnology holds the potential for products that could transform existing industries and create new ones, clean and

[4] *Nanotechnology Takes a Deep Breath…and Prepares to Save the World*, Cientifica, April 2009, available at http://www.cientifica.eu/files/Whitepapers/Nanotechnology%20Takes%20a%20Deep%20Breath.pdf.

[5] The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel, President's Council of Advisors on Science and Technology, May 2005, available at http://www.nano.gov/html/res/FINAL_PCAST_NANO_REPORT.pdf.

[6] *Nanotechnology Takes a Deep Breath…and Prepares to Save the World*, Cientifica, April 2009, available at http://www.cientifica.eu/files/Whitepapers/Nanotechnology%20Takes%20a%20Deep%20Breath.pdf.

[7] Ibid.

[8] "Overhyped Technology Starts to Reach Potential," press release, Lux Research, July 22, 2008. http://www.luxresearchinc.com/press/RELEASE_Nano-SMR_7_22_08.pdf. Numbers do not add to total due to rounding.

protect the environment, extend and improve the quality of our lives, and strengthen national security. Most nanotechnology products currently on the market—such as faster computer processors, higher density memory devices, lighter-weight auto parts, stain-resistant clothing, antibiotic bandages, cosmetics, and clear sunscreen—are evolutionary in nature, offering incremental improvements in characteristics such as performance, aesthetics, cost, size, and weight.

Evolutionary nanotechnology products, however, represent only a small fraction of what many see as the substantial longer-term economic and societal promise of nanotechnology. One estimate projects nanotechnology product revenues will reach $3.1 trillion by 2015,[9] while another estimate projects revenues will reach $2.95 billion by 2015, of which almost half will come from semiconductors.[10, 11]

Many nanotechnology advocates—including business executives, scientists, engineers, medical professionals, and venture capitalists—assert that in the longer term, nanotechnology, especially in combination with information technology, biotechnology, and the cognitive sciences, may deliver revolutionary advances, including:

- new prevention, detection, and treatment technologies that could reduce substantially death and suffering from cancer and other deadly illnesses;[12]
- new organs to replace damaged or diseased ones;[13]
- contact lenses, skin patches, and glucose-sensing tattoos that monitor diabetics' blood sugar levels and warn when too high or low;[14]
- clothing that protects against toxins and pathogens;[15]
- clean, inexpensive, renewable power through energy creation, storage, and transmission technologies;[16]
- inexpensive, portable water purification systems that provide universal access to safe water;[17]
- energy efficient, low-emission "green" manufacturing systems;[18]

[9] Ibid

[10] *Halfway to the Trillion Dollar Market: A Critical Review of the Diffusion of Nanotechnologies*, Cientifica, 2007. http://www.cientifica.eu/files/Whitepapers/A%20Reassessment%20of%20the%20Trillion%20WP.pdf

[11] While views vary on how to calculate nanotechnology's contribution to these products, the consensus is that nanotechnology is likely to have a significant economic impact and transformative effect on many industries.

[12] National Cancer Institute website. http://nano.cancer.gov/resource_center/tech_backgrounder.asp

[13] Ibid.

[14] Aslan, Kadir; Lakowicz, Joseph R.; and Geddes, Chris D. "Nanogold plasmon resonance-based glucose sensing. Wavelength-ratiometric resonance light scattering," *Analytical Chemistry*, 2005, Vol. 77. *Strategic Plan for Pediatric Urology*, National Institute of Diabetes and Digestive and Kidney Disease, National Institutes of Health, Department of Health and Human Services, February 2006.

[15] Risbud, Aditi. "Fruit of the Nano Loom," *Technology Review*, February 2006.

[16] *Nanoscience Research for Energy Needs*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, December 2004.

[17] Risbud, Aditi. "Cheap Drinking Water from the Ocean," *Technology Review*, June 2006.

[18] Selko, Adrienne. "New Nanotechnology-Based Coatings Are Energy Efficient and Environmentally Sound," *Industry Week*, August 22, 2007. "Tomorrow's Green Nanofactories," *Science Daily*, July 11, 2007.

- high-density memory systems capable of storing the entire Library of Congress collection on a device the size of a sugar cube;[19]
- agricultural technologies that increase crop yield and improve nutritional value, reducing global hunger and malnutrition;[20]
- self-repairing materials;[21]
- powerful, small, inexpensive sensors that can warn of minute levels of toxins and pathogens in air, soil, or water;[22] and
- decontaminated industrial sites through environmental remediation.[23]

While some applications of nanotechnology have proven market-ready, much fundamental research remains ahead, including efforts to advance understanding of nanoscale phenomena; characterize nanoscale materials; understand how to control and manipulate nanoscale particles; develop instrumentation and measurement methods; and understand how nanoscale particles interact with humans, animals, plants, and the environment. In addition, several federal agencies—such as the Departments of Defense, Energy, and Homeland Security—see the potential for nanotechnology to help address mission requirements. Historically, the federal government has played a central role in funding these types of research and development activities.

Though federal nanoscale science, engineering, and technology R&D had been underway for over a decade, the NNI was first initiated as a Presidential technology initiative in 2000.[24] The original participating agencies were the National Science Foundation (NSF), the Department of Defense (DOD), the Department of Energy (DOE), the Department of Commerce's (DOC) National Institute of Standards and Technology (NIST), the National Aeronautics and Space Administration (NASA), and the Department of Health and Human Services' National Institutes of Health (NIH). In 2009, 25 agencies participated in the NNI, including 13 that received appropriations to conduct and/or fund nanotechnology R&D. Since its first year of funding in

[19] *National Nanotechnology Initiative—Leading to the Next Industrial Revolution*, Interagency Working Group on Nanoscience, Engineering, and Technology, National Science and Technology Council, The White House. http://www.ostp.gov/NSTC/html/iwgn/iwgn.fy01budsuppl/nni.pdf

[20] *21st Century Agriculture: A Critical Role for Science and Technology*, U.S. Department of Agriculture, June 2003; and *Nanoscale Science and Engineering for Agriculture and Food Systems*: *Draft Report of the National Planning Workshop to the Cooperative State Research, Education, and Extension Service of the U.S. Department of Agriculture*, July 2003.

[21] *Nanotechnology in Space Exploration*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, August 2004, available at http://www.nano.gov/nni_space_exploration_rpt.pdf.

[22] *Nanotechnology and the Environment*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, May 2003, available at http://www.nano.gov/NNI_Nanotechnology_and_the_Environment.pdf.

[23] *Proceedings of the U.S. Environmental Protection Agency Workshop on Nanotechnology for Site Remediation,* U.S. Environmental Protection Agency, October 2005.

[24] "National Nanotechnology Initiative: Leading to the Next Industrial Revolution," press release, The White House, January 21, 2000. http://clinton4.nara.gov/WH/New/html/20000121_4.html; and "Steering the technology that will redefine life as we know it," *Industrial Biotechnology*, Vol. 1, No. 3, Fall 2005. http://www.nsf.gov/crssprgm/nano/reports/mcr_ind_biotech_interview.pdf

FY2001, the NNI's annual appropriations have grown nearly four-fold to an estimated $1.8 billion in FY2010.[25]

In 2003, Congress provided a statutory foundation for some of the activities of the NNI through the 21st Century Nanotechnology Research and Development Act of 2003 (P.L. 108-153). The act established a National Nanotechnology Program (NNP) and provided authorizations for a subset of the NNI agencies, namely the NSF, DOE, NASA, NIST, and Environmental Protection Agency (EPA).[26] The act, however, did not address the participation of several agencies that fund nanotechnology R&D under the NNI, including DOD, NIH, and the Department of Homeland Security (DHS). Nevertheless, coordination of nanotechnology R&D activities across all NNI funding agencies continues under the National Science and Technology Council's (NSTC's) Nanoscale Science, Engineering, and Technology (NSET) subcommittee.[27] According to the NSET subcommittee's 2004 NNI Strategic Plan, "For continuity and to capture this broader participation, the coordinated federal activities as a whole will continue to be referred to as the National Nanotechnology Initiative." Accordingly, the functions and activities established under the act are incorporated into the Executive Branch's implementation of the NNI.

The thrust of the NNI has primarily been the development of fundamental scientific knowledge through basic research. Investments at mission agencies, such as DOD, have supported nanotechnology applications development for which they are a primary customer. Other investments have supported infrastructural technologies. For example, NIST has contributed to developing tools and standards that enable measurement and control of matter at the nanoscale, thereby supporting the conduct of R&D and the ability to manufacture nanoscale materials and products. As understanding of nanotechnology has matured, the NNI has worked with a variety of industry organizations to facilitate the movement of research results from the laboratory bench to the marketplace in fields as disparate as semiconductors, chemicals, energy, concrete, and forest products.

The NNI agencies also have begun to address research needs and regulatory issues related to environmental, health, and safety issues, as well as issues such as public understanding and workforce education and training. The NNI agencies actively engage in a variety of international fora, such as the Organization for Economic Cooperation and Development (OECD) and the International Standards Organization (ISO), to cooperatively address nanotechnology issues related to EHS, metrology[28] and standards, nomenclature, and nanoscale materials characterization.

[25] This figure includes $1.657 billion in regular appropriations and $0.140 billion in funding provided by the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

[26] While many provisions of this act have no sunset provision, FY2008 was the last year of agency authorizations included in the act.

[27] Prior to P.L. 108-153, the Bob Stump Defense Authorization Act for Fiscal Year 2003 (P.L. 107-314) required DOD to "provide for interagency cooperation and collaboration on nanoscale research and development." The NSET subcommittee is a subcommittee of the NSTC Committee on Technology.

[28] Metrology is the science of measurement, including the equipment and processes used to produce a measurement.

Maintaining U.S. leadership poses a variety of technical, economic, and policy challenges, including:

- safeguarding the environment and ensuring human health and safety;
- creating the standards, reference materials, nomenclature, methods, and tools for metrology to enable the manufacturing of nanoscale materials and products;
- developing a world-class scientific and technical nanotechnology workforce;
- translating research results into products, including effective technology transfer to the private sector;
- understanding public perceptions and attitudes and fostering public understanding;
- addressing ethical, legal and societal implications;
- protecting intellectual property;
- securing investment capital for early-stage research, development, and commercialization; and
- fostering and facilitating international cooperation and coordination.

Proponents of the NNI assert that nanotechnology is one of the most important emerging and enabling technologies[29] and that U.S. competitiveness, technological leadership, national security, and societal interests require an aggressive approach to the development and commercialization of nanotechnology. Critics of the NNI hold a variety of competing views, asserting that government is not doing enough, is doing too much, or is moving too quickly.

Some in industry have criticized the NNI for being overly focused on basic research and not being aggressive enough in moving NNI-funded R&D out of government and university laboratories and into industry. Others in industry have criticized the federal government for not providing mechanisms to help advance nanotechnology R&D to the point where it becomes economically viable for venture capitalists, corporations, and other investors to create products and bring them to market. Some refer to this gap as the "valley of death."[30] Still others in industry have criticized the NNI for not adequately supporting the development of metrology, standards, equipment, and processes necessary to manufacture nanotechnology materials, products, and systems at a commercial scale.

Conversely, supporters of industry-driven market investments contend that extensive government support for nanotechnology may supplant the judgment of the marketplace by picking "winners and losers" in technological development. For example, the size and directions of the NNI investments may encourage industry to follow the government's lead rather than independently selecting R&D directions itself or, alternatively, may result in the promotion of a less effective

[29] The Department of Commerce has characterized emerging and enabling technologies as those that "offer a wide breadth of potential application and form an important technical basis for future commercial applications." (ATP Rule, 15 C.F.R. Part 295).

[30] The term "valley of death" is used by business executives, economists, and venture capitalists to describe the development gap that often exists between a laboratory discovery and the market's willingness to invest to advance the discovery to a final commercial product. This gap occurs due to a variety of issues, such as technical risk, market uncertainty, and likelihood of obtaining an adequate return on investment.

technology path over a more effective one. These supporters also assert that federal government funding of scientific research is often wasteful, driven by political considerations and not scientific merit.[31]

Some non-governmental organizations (NGO) are critical of nanotechnology for its potential adverse impacts on human health and safety and on the environment. They assert that the government is pushing ahead too quickly in developing nanotechnology and encouraging its commercialization and use without adequately investing in research focused on understanding and mitigating negative EHS implications.[32] They argue that the very characteristics that make nanotechnology promising also present significant potential risks to human health and safety and the environment. Some of these critics argue for application of the "precautionary principle," which holds that regulatory action may be required to control potentially hazardous substances even before a causal link has been established by scientific evidence.[33] At least one NGO has called for a moratorium on nanotechnology R&D and new commercial products incorporating synthetic nanoparticles.[34]

National Nanotechnology Initiative

The National Nanotechnology Initiative is an interagency program that coordinates federal nanoscale science, engineering, and technology R&D activities and related efforts among participating agencies.

Vision and Goals

The National Science and Technology Council (NSTC) has stated the following vision for the NNI:

> A future in which the ability to understand and control matter on the nanoscale leads to a revolution in technology and industry. The NNI will expedite the discovery, development, and deployment of nanotechnology in order to achieve responsible and sustainable economic benefits, to enhance the quality of life, and to promote national security.[35]

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[31] Crews, Clyde Wayne, Jr., "Washington's Big Little Pork Barrel: Nanotechnology," Cato Institute website, May 29, 2003.

[32] Testimony of Andrew Maynard, Chief Science Advisor, Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars, "Research on Environmental and Safety Impacts of Nanotechnology: Current Status of Planning and Implementation under the National Nanotechnology Initiative," hearing, Subcommittee on Research and Science Education, House Committee on Science and Technology, October 31, 2007.

[33] "NGOs urge precautionary principle in use of nanomaterials," EurActiv.com, June 14, 2007. http://www.euractiv.com/en/environment/ngos-urge-precautionary-principle-use-nanomaterials/article-164619 Sass, Jennifer. "Nanotechnology and the Precautionary Principle," presentation, Natural Resources Defense Council, 2006. http://docs.nrdc.org/health/hea_06121402a.pdf The precautionary principle has been used in other countries on some issues. For example, the Biosafety Protocol to the 1992 Convention on Biological Diversity incorporates provisions applying the precautionary principle to the safe handling, transfer, and trade of genetically modified organisms. For further information, see CRS Report RL30594, *Biosafety Protocol for Genetically Modified Organisms: Overview*, by Alejandro E. Segarra and Susan R. Fletcher.

[34] "No Small Matter II: The Case for a Global Moratorium—Size Matters!," Occasional Paper Series, ETC Group, April 2003. http://www.etcgroup.org/upload/publication/pdf_file/165

[35] *The National Nanotechnology Initiative Strategic Plan*, Nanoscale Science, Engineering, and Technology (continued...)

To achieve its vision, the NNI has established four goals: maintain a world-class R&D program aimed at realizing the full potential of nanotechnology; facilitate transfer of new technologies into products that provide economic growth, jobs, and other public benefits; develop educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; and support responsible development of nanotechnology.[36]

History

Attempts to coordinate federal nanoscale R&D began in November 1996, as staff members from several agencies met regularly to discuss their plans and programs in nanoscale science and technology. This group continued informally until September 1998, when it was designated as the Interagency Working Group on Nanotechnology (IWGN) under the NSTC. In August 1999, IWGN completed its first draft of a plan for an initiative in nanoscale science and technology, which was subsequently approved by the President's Council of Advisors on Science and Technology (PCAST) and the White House Office of Science and Technology Policy (OSTP).[37]

In his 2001 budget submission to Congress, then-President Clinton raised nanotechnology-related research to the level of a federal initiative, officially referring to it as the National Nanotechnology Initiative.[38]

Legislative Approach

Congress has played a central role in the National Nanotechnology Initiative, providing appropriations for the conduct of nanoscale science, engineering, and technology research; establishing programs; and creating a legislative foundation for the activities of the NNI.

Congressional funding for the NNI is provided through appropriations to each of the NNI-participating agencies. The NNI has no centralized funding. The overall NNI budget is calculated by aggregating the nanotechnology budgets for each of the federal agencies that conduct or provide funding for nanoscale science, engineering, and technology research.

In FY2001, the first year of NNI funding, Congress provided $464 million to eight agencies for nanoscale science, engineering, and technology research.[39] The NNI has continued to receive support from both Congress and the White House. Both the number of agencies participating in the NNI and the size of the federal investment have grown. Currently 25 agencies participate in

(...continued)

Subcommittee, National Science and Technology Council, The White House, December 2004, available at http://www.nano.gov/NNI_Strategic_Plan_2004.pdf.

[36] Ibid.

[37] National Nanotechnology Initiative website. http://www.nano.gov/html/about/history.html

[38] "National Nanotechnology Initiative: Leading to the Next Industrial Revolution," press release, The White House, January 21, 2000. http://clinton4.nara.gov/WH/New/html/20000121_4.html; and National Nanotechnology Initiative website. http://www.nano.gov/html/about/history.html

[39] In its January 21, 2001 press release, "National Nanotechnology Initiative: Leading to the Next Industrial Revolution," announcing the establishment of the NNI, the White House identified only six participating agencies—NSF, DOD, DOE, NIST, NASA, and NIH. Subsequently, EPA and DOJ reported nanotechnology R&D funding in FY2001, bringing the total number of agencies funding nanotechnology R&D in FY2001 to eight.

the NNI, 13 of which have received appropriated funds for nanotechnology R&D in FY2009.[40] Total NNI funding in FY2009 is approximately $1.8 billion, more than three times the level of funding provided in FY2001. The original six agencies identified at the launch of the NNI[41] still account for the vast majority of NNI funding (97.3% in FY2009; detailed agency funding levels for FY2010 are not yet available).

21st Century Nanotechnology Research and Development Act of 2003

Congress codified and further defined some of the NNI's activities in the 21st Century Nanotechnology Research and Development Act of 2003 which was passed by Congress in November 2003, and signed into law (P.L. 108-153) by President Bush on December 3, 2003.[42] The legislation received strong bipartisan support in both the House of Representatives, which passed the bill on a recorded vote of 405-19, and in the Senate, which passed the bill by unanimous consent.

Though this act is often referred to as the enabling legislation for the National Nanotechnology Initiative, the act actually establishes a National Nanotechnology Program (NNP). The act provides authorizations for five NNI agencies—the National Science Foundation, Department of Energy, NASA, National Institute of Standards and Technology, and Environmental Protection Agency—but not for the Department of Defense, National Institutes of Health, Department of Homeland Security,[43] or other NNI research agencies that collectively accounted for 46% of NNI funding in FY2003.

The act created the NNP for the purposes of establishing the goals, priorities, and metrics for evaluation of federal nanotechnology research, development, and other activities; investing in federal R&D programs in nanotechnology and related sciences to achieve those goals; and providing for interagency coordination of federal nanotechnology research, development, and other activities undertaken pursuant to the NNP.

[40] NNI participants include agencies that either conduct or provide funding for nanotechnology R&D, as well as agencies with missions that may affect the development, commercialization, and use of nanotechnology. For example, in the latter case, the Food and Drug Administration may regulate (or not regulate) nanotechnology products, the U.S. Patent and Trademark Office's (USPTO) treatment of nanotechnology-related patents may affect the value of the underlying intellectual property, and the execution of the missions of the Departments of Education and Labor could affect the preparedness of the U.S. workforce for emerging nanotechnology jobs. Some nanotechnology R&D agencies may also have non-R&D missions related to nanotechnology. For example, EPA conducts and funds R&D but also has a regulatory mission that could affect nanotechnology research, development, production, use, and/or disposal.

[41] The original six agencies identified at the launch of the NNI were the Department of Defense, Department of Energy, National Institute of Standards and Technology (Department of Commerce), National Science Foundation, National Aeronautics and Space Administration, and National Institutes of Health (DHHS). "National Nanotechnology Initiative: Leading to the Next Industrial Revolution," press release, The White House, January 21, 2000. http://clinton4.nara.gov/WH/New/html/20000121_4.html; and National Nanotechnology Initiative website. http://www.nano.gov/html/about/history.html

[42] U.S. Congress. 2003. 21st Century Nanotechnology Research and Development Act. P.L. 108-153. 15 U.S.C. 7501. 108 Cong., December 3.

[43] FY2003 funding attributed to DHS for the purpose of this calculation is based on nanotechnology R&D appropriations received by the Department of Transportation's Transportation Security Administration (TSA). TSA was transferred to DHS in the Homeland Security Act of 2002 (P.L. 107-296) which was enacted after the start of FY2003.

Key provisions of the act include:

- authorizing appropriations for the nanotechnology-related activities of the National Science Foundation, Department of Energy, NASA, National Institute of Standards and Technology, and Environmental Protection Agency for fiscal years 2005 through 2008, totaling $3.679 billion for the four year period;
- establishing a National Nanotechnology Coordination Office, with a director and full time staff to provide administrative support to the NSTC;
- establishing a National Nanotechnology Advisory Panel (NNAP) to advise the President and the NSTC on matters relating to the NNP.
- establishing a triennial review of the NNP by the National Research Council of the National Academies of Sciences;
- directing the NSTC to oversee the planning, management, and coordination of the program, including the development of a triennial strategic plan;
- directing the Department of Commerce's National Institute of Standards and Technology to establish a program to conduct basic research on issues related to the development and manufacture of nanotechnology, and to use the Manufacturing Extension Partnership program to ensure results reach small- and medium-sized manufacturing companies;
- directing the Secretary of Commerce to use the National Technical Information Service to establish a clearinghouse of information related to commercialization of nanotechnology research;
- directing the Secretary of Energy to establish a program to support consortia to conduct interdisciplinary nanotechnology R&D designed to integrate newly developed nanotechnology and microfluidic tools with systems biology and molecular imaging;
- directing the Secretary of Energy to carry out projects to develop, plan, construct, acquire, operate, or support special equipment, instrumentation, or facilities for investigators conducting nanotechnology R&D; and
- directing the establishment of two centers, on a merit-reviewed and competitive basis: (1) the American Nanotechnology Preparedness Center, to conduct, coordinate, collect, and disseminate studies on the societal, ethical, environmental, educational, legal, and workforce implications of nanotechnology; and to identify anticipated issues related to the responsible research, development, and application of nanotechnology, as well as provide recommendations for preventing or addressing such issues, and (2) the Center for Nanomaterials Manufacturing, to encourage, conduct, coordinate, commission, collect, and disseminate research on new manufacturing technologies for materials, devices, and systems with new combinations of characteristics, such as, but not limited to, strength, toughness, density, conductivity, flame resistance, and membrane separation characteristics; and to develop mechanisms to transfer such manufacturing technologies to U.S. industries.

While the act establishes a National Nanotechnology Program, the Executive Branch continues its broader effort under the NNI framework and name. According to the NNI's 2004 Strategic Plan:

> Many of the activities outlined in the Act were already in progress as part of the NNI. Moreover, the ongoing management of the initiative involves considerable input from Federal agencies that are not named specifically in the Act.... For continuity, and to capture this broader participation, the coordinated Federal activities as a whole will continue to be referred to as the National Nanotechnology Initiative.[44]

Reauthorization Efforts

The 21st Century Nanotechnology Research and Development Act provided a legislative foundation for some of the activities of the NNI, authorized agency funding levels through FY2008, and sought to address challenges associated with the development and commercialization of nanotechnology. While many provisions of this act have no sunset provision, FY2008 was the last year of agency authorizations included in the act. Legislation to amend and reauthorize the act was introduced in the House (H.R. 5940, 110th Congress) and the Senate (S. 3274, 110th Congress) in the 110th Congress. Both bills were titled the National Nanotechnology Initiative Amendments Act of 2008. The House passed H.R. 5940 by a vote of 407-6; the Senate did not act on S. 3274.

In January 2009, H.R. 554, the National Nanotechnology Initiative Amendments Act of 2009, was introduced in the 111th Congress. The act contains essentially the same provisions as H.R. 5940 (110th Congress). (For additional information on H.R. 554, see bill highlights on page 38.) In February 2009, the House passed the bill by voice vote under a suspension of the rules. In July 2009, S. 1482, the National Nanotechnology Initiative Amendments Act of 2009, was introduced in the Senate. The bill was referred to the Senate Committee on Commerce, Science, and Transportation. No further action has been taken. H.R. 820, the Nanotechnology Advancement and New Opportunities Act, also would amend P.L. 108-153. The provisions of H.R. 820 cover a variety of jurisdictions, thus the bill has been assigned to multiple House committees. On May 7, 2010, the House Committee on Science and Technology reported the America COMPETES Reauthorization Act of 2010 (H.R. 5116) which includes, as Title I, Subtitle A, the "National Nanotechnology Initiative Amendments Act of 2010." Provisions of this subtitle are nearly identical to the provisions of H.R. 554. (For additional information on these bills, see "Selected Nanotechnology Legislation in the 111th Congress.")

Congress may use these bills to further address these issues and to establish authorization levels for agency nanotechnology R&D. Alternatively, Congress may choose to address some or all of these issues in separate legislation. Several bills have been introduced in the first session of the 111th Congress to address specific nanotechnology issues.

[44] *The National Nanotechnology Initiative Strategic Plan*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, December 2004, available at http://www.nano.gov/NNI_Strategic_Plan_2004.pdf.

Structure

Nanoscale Science, Engineering, and Technology Subcommittee

The NNI is coordinated within the White House through the NSTC, the Cabinet-level council by which the President coordinates science, space, and technology policies across the federal government. Operationally, NNI coordination is accomplished through the Nanoscale Science, Engineering, and Technology (NSET) subcommittee of the NSTC's Committee on Technology (CT). The NSET subcommittee also has an informal reporting relationship to the NSTC's Committee on Science (CS). The NSET subcommittee is led by an agency co-chair, currently from the Department of Energy (DOE), and an OSTP co-chair. The NSET subcommittee is comprised of representatives from 25 federal entities (including 15 that fund nanotechnology R&D), OSTP and the Office of Management and Budget.[45]

The NSET subcommittee has established several working groups, each taking on efforts in key subject areas.[46] Among them:

National Environmental and Health Implications (NEHI)

The National Environmental and Health Implications (NEHI) working group was chartered to provide for exchange of information among agencies that support research and those responsible for regulations and guidelines related to nanotechnology products; to facilitate identification, prioritization, and implementation of research and other activities required for the responsible research, development, utilization, and oversight of nanotechnology; and to promote communication of information related to research on environmental and health implications of nanotechnology to other government agencies and non-government parties. To this end, the NEHI working group seeks to identify and prioritize environmental, health, and safety research needs related to nanotechnology. Twenty NNI agencies participate in the NEHI working group, and 13 agencies fund safety-related nanotechnology research and/or have regulatory authorities to guide the safe use of nanomaterials.[47]

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[45] The agencies that participate in the NSET subcommittee comprise the NNI. NSET subcommittee members include Bureau of Industry and Security, Department of Commerce; Consumer Product Safety Commission; National Institute of Food and Agriculture, Department of Agriculture; Department of Defense; Department of Education; Department of Energy; Department of Homeland Security; Department of Justice; Department of Labor; Department of State; Department of Transportation; Department of the Treasury; Environmental Protection Agency; Food and Drug Administration; Forest Service, Department of Agriculture; Director of National Intelligence; International Trade Commission; National Aeronautics and Space Administration; National Institutes of Health, U.S. Department of Health and Human Services; National Institute for Occupational Safety and Health, Center for Disease Control, Department of Health and Human Services; National Institute of Standards and Technology, Department of Commerce; National Science Foundation; Nuclear Regulatory Commission; U.S. Geological Survey; and U.S. Patent and Trademark Office, Department of Commerce. The Department of Commerce's Technology Administration was a participating agency in the NNI until its elimination in August 2007 under the America COMPETES Act (P.L. 110-69).

[46] The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry-Supplement to the President's FY2008 Budget, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, July 2007, available at http://www.nano.gov/NNI_08Budget.pdf.

[47] Testimony of E. Clayton Teague, Director, National Nanotechnology Coordinating Office, *Research on Environmental and Safety Impacts of Nanotechnology: Current Status of Planning and Implementation under the* (continued...)

Nanomanufacturing, Industry Liaison, and Innovation(NILI)

The Nanomanufacturing, Industry Liaison, and Innovation (NILI) working group was chartered to enhance collaboration and information sharing between U.S. industry and government on nanotechnology-related activities. It also facilitates federal, regional, state, and local nanotechnology R&D and commercialization activities. In addition, the NILI working group is to create innovative methods for transferring federally funded technology to industry. The NILI working group has facilitated collaborations between the NNI and the semiconductor/electronics industry, chemical industry, forest products industry, and the Industrial Research Institute.[48]

Global Issues in Nanotechnology (GIN)

The Global Issues in Nanotechnology (GIN) working group was chartered to monitor foreign nanotechnology programs and development; broaden international collaboration on nanotechnology R&D, including safeguarding the environment and human health; and promote U.S. commercial and trade interests in nanotechnology. The NEHI working group works with the GIN working group to coordinate the U.S. position and participation in international activities related to environmental, health, and safety implications of nanotechnology. The GIN working group facilitates international collaboration on pre-competitive and non-competitive aspects of nanotechnology, and international engagement on trade, commercialization and regulatory issues.

Nanotechnology Public Engagement and Communications (NPEC)

The Nanotechnology Public Engagement and Communications (NPEC) working group was established to develop approaches by which the NNI can communicate more effectively with the public.

National Nanotechnology Coordination Office

The National Nanotechnology Coordination Office (NNCO) provides administrative and technical support to the NSET subcommittee. Initially established in 2001 through a memorandum of understanding among the NNI participating agencies,[49] the NNCO was authorized by the 21st Century Nanotechnology Research and Development Act of 2003 (P.L. 108-153). The NNCO was charged under the act with providing technical and administrative support to the NSTC and NNAP; serving as the point of contact for information on Federal nanotechnology activities for the exchange of technical and programmatic information among stakeholders; conducting public outreach; and promoting access to and early application of NNP technologies, innovation, and expertise.

The act authorizes the work of the NNCO to be funded by contributions from NSET subcommittee member agencies. According to the NNCO, funding is provided through a

(...continued)

National Nanotechnology Initiative, hearing, Subcommittee on Research and Science Education, House Committee on Science and Technology, October 31, 2007.

[48] The Industrial Research Institute is an association of companies and federally funded laboratories with the mission of improving R&D capabilities through the development and dissemination of best practices.

[49] National Nanotechnology Initiative website, http://www.nano.gov.

memorandum of understanding signed by eight NNI agencies.[50] In principle, each agency contributes to the NNCO budget in proportion to its share of the President's total nanotechnology budget request for the signatory agencies. However, two of the signatories, EPA and DOT, had sufficiently small enough nanotechnology budgets in the early years of the NNI that they were not expected to contribute. EPA now contributes to funding the NNCO. Total NNCO funding from the agencies in FY2010 is $2.4 million. In addition, the NNCO has carried over FY2009 funds intended to support a National Academies' study, bringing the total NNCO budget for FY2010 to just under $3 million.

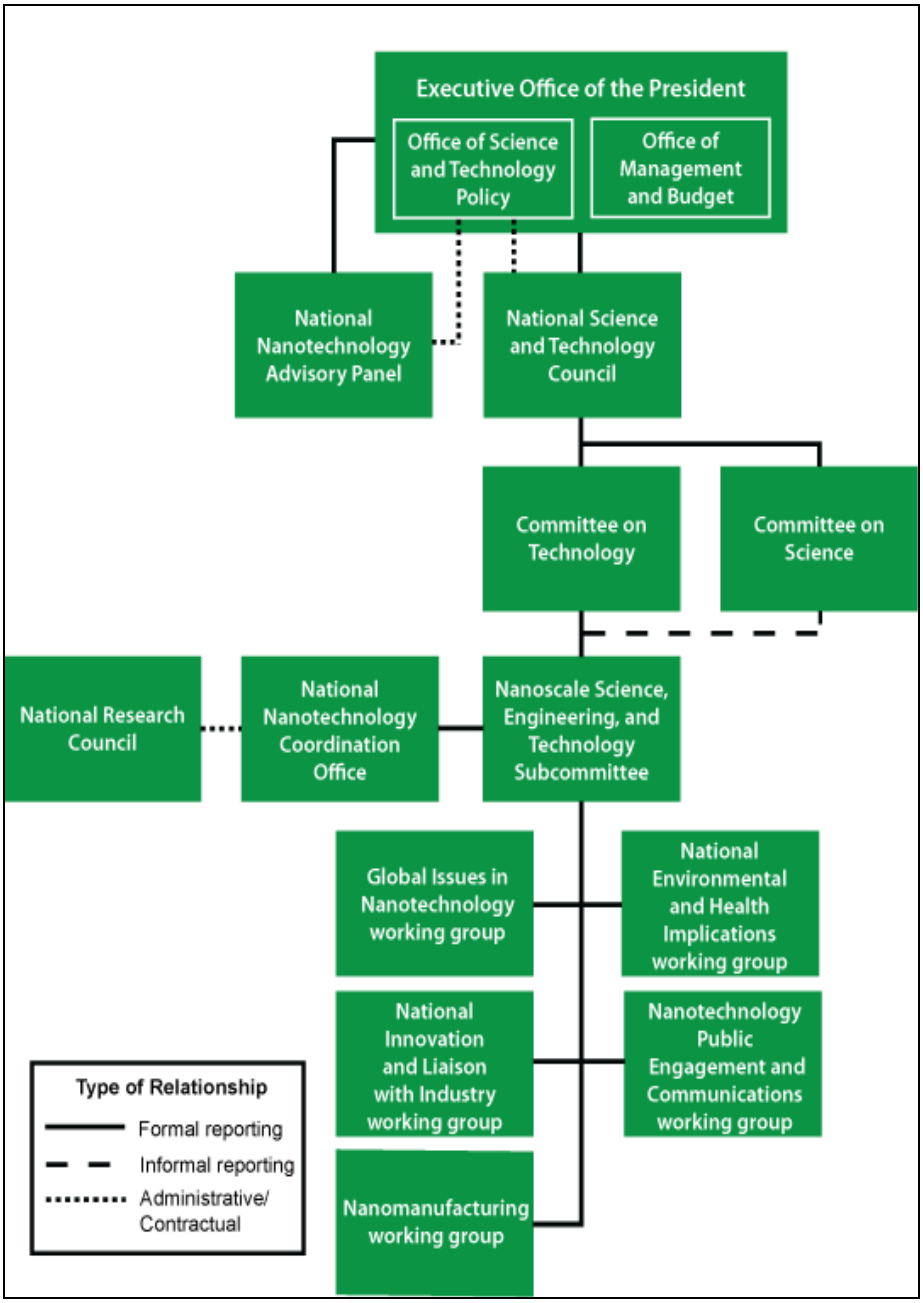
Funding

The NNI supports fundamental and applied research on nanotechnology by funding research, creating multidisciplinary centers of excellence, and developing key research infrastructure. It also supports activities aimed at addressing the societal implications of nanotechnology, including ethical, legal, human and environmental health, and workforce issues.

This section provides information on NNI funding from two perspectives: organizationally by agency and functionally by program component area.

[50] The eight agencies that are signatories to the memorandum of understanding are NSF, DOD, DOE, NIH, NIST, NASA, EPA, and DOT.

Figure 1. Organizations With a Role in the National Nanotechnology Initiative and Their Relationships



Source: *The National Nanotechnology Strategic Plan*, Nanoscale, Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, December 2007. (Nanomanufacturing working group added to chart in cited source.)

Agency Funding

The NNI budget is an aggregation of the nanotechnology components of the individual budgets of NNI-participating agencies. The NNI budget is not a single, centralized source of funds that is allocated to individual agencies. In fact, agency nanotechnology budgets are developed internally as part of each agency's overall budget development process. These budgets are subjected to review, revision, and approval by the Office of Management and Budget and become part of the President's annual budget submission to Congress. The NNI budget is then calculated by aggregating the nanotechnology components of the appropriations provided by Congress to each federal agency.

For FY2010, regular appropriations for NNI agencies totaled an estimated $1.781 billion,[51] a $79.5 million (4.7%) increase over the FY2009 regular appropriation and nearly four times the $464 million federal investment in nanotechnology research in FY2001. This growth in nanotechnology R&D investments reflects expectations in Congress and in the executive branch that the NNI will expand fundamental knowledge and make important contributions to national priorities. The chronology of NNI funding is detailed in **Table 1**.

President Obama has requested $1.762 billion in funding for the NNI in FY2011, a decrease of $19.5 million (1.1%). The FY2011 NNI budget request would support a broad range of programs among 13 agencies. Agencies with the largest budgets are:

- NSF, which supports fundamental nanotechnology research across science and engineering disciplines;
- DOD, whose investments in nanotechnology are aimed at addressing the department's national security mission;
- DOE, which supports nanotechnology research providing a basis for new and improved energy efficiency, production, storage, and transmission technologies;
- NIH, which emphasizes nanotechnology-based biomedical advances occurring at the intersection of biology and the physical sciences; and
- NIST, which focuses on research in instrumentation, measurement, standards, characterization, and nanomanufacturing.

Other agencies investing in mission-related nanotechnology R&D are NASA, EPA, the Cooperative State Research, Education, and Extension Service (CSREES) and Forest Service at the Department of Agriculture (USDA), National Institute of Occupational Safety and Health (NIOSH), DHS, Department of Justice (DOJ), and Department of Transportation's (DOT's) Federal Highway Administration (FHWA).

[51] This figure does not include NNI funding provided by ARRA. Agency ARRA allocations included $511.2 million for nanotechnology R&D. Agencies may report additional ARRA funding for SBIR and STTR projects later, when 2009 SBIR/STTR data become available.

Table 1. NNI Funding, by Agency: FY2001-FY2009 and FY2010 Request

(in millions of current dollars)

Agency	FY 2001 Actual	FY 2002 Actual	FY 2003 Actual	FY 2004 Actual	FY 2005 Actual	FY 2006 Actual	FY 2007 Actual	FY 2008 Actual	FY 2009 Actual	ARRA (P.L. 111-5)[a]	FY2010 Estimate	FY2011 Request
National Science Foundation	150	204	221	256	335	360	389	409	409	101	418	401
Department of Defense[b]	125	224	220	291	352	424	450	460	459		436	349
Department of Energy	88	89	134	202	208	231	236	245	333	293	373	424
National Institutes of Health (HHS)	40	59	78	106	165	192	215	305	343	73	361	382
Nat'l Inst. of Standards and Tech. (DOC)	33	77	64	77	79	78	88	86	93	43	114	108
Environmental Protection Agency	5	6	5	5	7	5	8	12	12		18	20
NASA	22	35	36	47	45	50	20	17	14		14	16
Department of Justice	1	1	1	2	2	<1	2	0	1		0	
Department of Homeland Security		2	1	1	1	2	2	3	9		12	12
Nat'l Inst. of Food and Agriculture (USDA)[c]			1	2	3	4	4	6	10		10	9
Nat'l Inst. for Occupational Safety (HHS)					3	4	7	7	7		10	17
Forest Service (USDA)						2	3	5	5		5	5
Federal Highway Administration (DOT)						1	1	1	1		3	2
Food and Drug Administration (HHS)									7		7	15
Consumer Product Safety Commission									<1		<1	2
TOTAL[d]	464	697	760	989	1,200	1,351	1,425	1,554	1,702	511	1,781	1,762

Sources: NNI website, http://www.nano.gov.

a. Funding figures for nanotechnology-related R&D under the ARRA are preliminary estimates.

b. According to NSTC, the DOD budgets shown above for FY2006, FY2007, FY2008, and FY2009 include congressionally directed funding of approximately $76 million in FY2006, $63 million in FY2007, and $117 million in FY2009; the NSTC states that the DOD budget for FY2010 also includes congressionally directed funding but does not provide an amount. According to NSTC, the 2008 DOD estimate "includes many earmarks that are outside the NNI plan."

c. Formerly, the USDA Cooperative State Research, Education, and Extension Service (CSREES).

d. Totals may not add due to rounding of agency budget figures.

Program Component Area Funding

The 21st Century Nanotechnology R&D Act of 2003 called for the NSET subcommittee to develop categories of investment called Program Component Areas (PCA) to provide a means by which Congress and the executive branch can be informed of and direct the relative investments in these areas. The PCAs are categories of investments that cut across the needs and interests of individual agencies and contribute to the achievement of one or more of the NNI's goals. The 2004 NNI strategic plan identified seven PCAs. The 2007 NNI strategic plan splits the seventh PCA, Societal Dimensions, into two PCAs: Environment, Health, and Safety; and Education and Societal Dimensions. A description of the seven initial PCAs and their current funding are provided below,[52] as well as a description of the two derivative PCAs.[53] The chronology of NNI funding by PCA is detailed in **Table 2**.

In the following analysis of funding for each of the PCAs, comparisons involving FY2009 funding (i.e., between FY2010 and FY2009) exclude ARRA funding. In addition, comparisons between the President's FY2011 budget request and estimated FY2010 appropriations may be affected by the President's exclusion of congressionally directed funding in his budget.

[52] *The National Nanotechnology Initiative Strategic Plan,* Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, December 2004, http://www.nano.gov/NNI_Strategic_Plan_2004.pdf.

[53] *The National Nanotechnology Initiative Strategic Plan,* Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, December 2007, available at http://www.nano.gov/NNI_Strategic_Plan_2007.pdf.

Table 2. NNI Funding, by Program Component Area, FY2006-FY2009

(in millions of current dollars)

PCA	FY2006 Actual	FY2007 Actual	FY2008 Actual	FY2009 Actual	ARRA Preliminary	FY2010 Estimate	FY2011 Request
Fundamental Phenomena and Processes	455.9	480.6	478.5	479.2	130.6	467.9	484.4
Nanomaterials	265.1	258.3	285.1	331.9	178.3	373.5	342.3
Nanoscale Devices and Systems	319.6	344.7	372.7	435.2	68.0	429.9	402.0
Instrumentation Research, Metrology, and Standards	51.0	52.5	69.0	90.8	12.4	84.3	76.9
Nanomanufacturing	33.8	48.1	47.1	75.6	28.5	96.7	101.4
Major Research Facilities and Instrumentation Acquisition	152.4	152.4	196.4	177.6	72.5	197.3	203.0
Societal Dimensions	73.5						
- Environment, Health, and Safety		48.3	67.9	74.5	12.0	91.6	116.9
- Education & Societal Dimensions		39.2	37.7	36.8	9	39.9	34.8
TOTAL[a]	**1,351.2**	**1,424.1**	**1,554.4**	**1,701.5**	**511.3**	**1,781.1**	**1,761.6**

Source: *The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY2008 Budget*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, July 2007. *National Nanotechnology Initiative: FY2009 Budget & Highlights*, National Science and Technology Council, The White House, February 2008. *The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY2010 Budget*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, May 2009.

a. Details may not add to totals due to rounding.

Fundamental Phenomena and Processes

Fundamental Phenomena and Processes includes investments in the discovery and development of fundamental knowledge pertaining to the new phenomena in the physical, biological, and engineering sciences that occur at the nanoscale, as well as in understanding and articulation of scientific and engineering principles related to nanoscale structures, processes, and mechanisms.

FY2010 funding for Fundamental Phenomena and Processes fell to $467.9 million, down $11.3 million (2.4%) from the FY2009 level due primarily to a decrease in DOD funding in this PCA (down $24.0 million, 14.7%). President Obama's FY2011 budget proposes $484.4 million in funding, up $16.5 million (3.5%) over the FY2010 level due primarily to increases in DOE ($14.2 million, 13.8%) and DOD ($412.7 million, 9.1%) funding. The increase in DOE and DOD funding would somewhat offset by a decrease in NSF funding of $12.5 million (8.2%).[54]

Nanomaterials

Nanomaterials includes research investments to discover novel nanoscale and nanostructured materials. This PCA also attempts to understand the properties of nanomaterials, and supports R&D to enable the design and synthesis, in a controlled manner, of nanoscale materials with targeted properties.

FY2010 funding for Nanomaterials rose to $373.5 million, up $41.6 million (12.5%) from the FY2009 level, led by an increase in DOE funding in this PCA (up $21.7 million, 23.4%). President Obama's FY2011 budget proposes $342.3 million for this PCA, a decrease of $31.2 million (8.4%) from the FY2010 level, resulting primarily from reduced DOD funding (down $36.0 million, 47.8%).[55]

Nanoscale Devices and Systems

Nanoscale Devices and Systems include R&D investments that apply nanoscale science and engineering principles to create novel devices and systems or to improve existing ones. It also includes the use of nanoscale or nanostructured materials to achieve improved performance or new functionality. To meet this definition, the enabling science and technology must be at the nanoscale, but the systems and devices are not restricted to that size.

Funding for Nanoscale Devices and Systems fell to $429.9 million in FY2010, down $5.3 million (1.2%) from the FY2009 level. President Obama's FY2011 budget proposes $402.0 million in funding for this PCA, a decrease of $27.9 million (6.5%) from the FY2010 level, largely due to reductions in DOD funding (down $49.0 million, 33.1%). The decrease in DOD funding for this PCA would somewhat offset by increases in DOE ($13.2 million, 76.7%) and NIH funding ($13.1 million, 7.2%).[56]

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[54] *The National Nanotechnology Initiative: FY2010 Budget & Highlights*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, May 2009, available at http://www.nano.gov/NNI_2010_budget_supplement.pdf.

[55] Ibid.

[56] Ibid.

Instrumentation Research, Metrology, and Standards

The Instrumentation Research, Metrology, and Standards PCA includes R&D investments for development of tools needed to advance nanotechnology research and commercialization. Instrumentation for characterization, measurement, synthesis, and design of nanotechnology materials, structures, devices, and systems is funded through this PCA. R&D and other activities related to development of standards, including standards for nomenclature, materials, characterization, testing, and manufacture are also in this PCA.

FY2010 funding for Instrumentation Research, Metrology, and Standards fell to $84.3 million, down $6.5 million (7.2%) from the FY2009 level. President Obama's FY2011 budget proposes $76.9 million in funding for this PCA, a decrease of $7.4 million (8.8%) from the FY2010 level, due to decreases in DOD, DOE, and NSF funding.[57]

Nanomanufacturing

Nanomanufacturing R&D supports the development of scalable, reliable, cost-effective manufacturing of nanoscale materials, structures, devices, and systems. It also includes R&D and integration of ultra-miniaturized top-down processes and complex bottom-up processes.[58]

FY2010 funding for Nanomanufacturing rose to $96.7 million, up $21.1 million (27.9%) over the FY2009 level due primarily to increases in NIST ($17.8 million, 189.4%) and DOD ($8.2 million, 28.3%) funding. President Obama's FY2011 budget proposes $101.4 million for this PCA, an increase of $4.7 million (4.9%) above the FY2010 level as increases in DOE ($13.9 million, 198.6%) and NSF ($9.8 million, 43.8%) would more than offset decreases in DOD ($12.1 million, 32.5%) and NIST ($7.0 million, 25.7%) funding.[59]

Major Research Facilities and Instrumentation Acquisition

This PCA includes investments in the establishment and ongoing operations of user facilities and networks, the acquisition of major instrumentation, and other activities related to infrastructure for the conduct of nanoscale science, engineering, and technology R&D.

FY2010 funding for Major Research Facilities and Instrumentation Acquisition rose to $197.3 million, an increase of $19.7 million (11.1%) over the FY2009 level. President Obama's FY2011 budget proposes $203.0 million for this PCA, an increase of $5.7 million (2.9%) above the FY2009 level, led by increases in DOE and DOD funding.[60]

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[57] Ibid.

[58] Top-down processes are those that achieve design features by removing material from a larger block of material; bottom-up processes begin with smaller building blocks (atoms or molecules) and achieve design features by putting them together, possibly using self-assembly.

[59] *The National Nanotechnology Initiative: FY2010 Budget & Highlights*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, May 2009, available at http://www.nano.gov/NNI_2010_budget_supplement.pdf.

[60] Ibid.

Societal Dimensions

The Societal Dimensions PCA includes investments in research and other activities that address the broad implications of nanotechnology to society. This includes assessing benefits and risks through research directed at environmental, health, and safety impacts of nanotechnology development; risk assessment of such impacts; education-related activities, such as development of materials for schools, undergraduate programs, technical training, and public outreach; and research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, workforce, educational, ethical, and legal implications.

Under the 2007 NNI Strategic Plan, the Societal Dimensions PCA was divided into two separate PCAs: Environment, Health, and Safety, and Education and Societal Dimensions. Future PCA reporting will use the new eight PCA taxonomy. NSTC has retroactively reported FY2007 Societal Dimensions PCA spending in the new PCAs.[61] The NSET subcommittee characterizes the new PCAs as follows:[62]

Environment, Health, and Safety

This PCA addresses research primarily directed at understanding the environmental, health, and safety impacts of nanotechnology development and corresponding risk assessment, risk management, and methods for risk mitigation.

FY2010 funding for Environment, Health, and Safety rose to $91.6 million, up $17.1 million (23.0%) above the FY2009 level, due to increases in EPA, NIH, NSF, and NIOSH funding. President Obama's FY2011 budget proposes $116.9 million in funding for this PCA, an increase of $25.3 million (27.6%) above the FY2010 level, led by increases at FDA and NIOSH.[63]

Education and Societal Dimensions

This PCA addresses education-related activities such as development of materials for schools, undergraduate programs, technical training, and public communication, including outreach and engagement. Such activities include research directed at identifying and quantifying the broad implications of nanotechnology society, including social, economic, workforce, educational, ethical, and legal implications.

FY2010 funding for Education and Societal Dimensions rose slightly to $39.9 million, up $3.1 million (8.4%) from the FY2009 level due primarily to an increase in NSF funding ($3.0 million, 9.6%); NSF accounts for 86.0% of funding in this PCA in FY2009. President Obama's FY2011 budget proposes $34.8 million in funding for this PCA, a decrease of $5.1 million (12.8%) from the FY2010 level, accounted for entirely by a decrease in NSF funding.[64]

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[61] *The National Nanotechnology Initiative: FY2010 Budget & Highlights*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, May 2009, available at http://www.nano.gov/NNI_2010_budget_supplement.pdf.

[62] Ibid.

[63] *The National Nanotechnology Initiative: FY2010 Budget & Highlights*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, May 2009, available at http://www.nano.gov/NNI_2010_budget_supplement.pdf.

[64] Ibid.

Centers, Networks, and User Facilities

A key facet of the National Nanotechnology Initiative has been the development of an extensive infrastructure of interdisciplinary research and education centers, networks, and user facilities. The centers and user facilities are located at universities and federal laboratories across the country.

Centers and networks provide opportunities and support for multidisciplinary research among investigators from a variety of disciplines and research sectors, including academia, industry, and government laboratories. Such multidisciplinary research not only can lead to advances in knowledge, but also may foster relationships that further the development of basic research results into devices and other applications.

Many agencies support such centers. Examples of federal and federally supported centers include:

- The National Science Foundation has established university-based centers focused exclusively on nanotechnology, including 15 Nanoscale Science and Engineering Centers (NSEC), one Engineering Research Center, one Science and Technology Center, four Materials Research Science and Engineering Centers, two Nanoscale Science and Engineering Education Centers, and five Nanoscale Science and Engineering Networks.[65]
- The NIH has established more than 20 centers, including eight university-based Nanomedicine Development Centers; a Nanotechnology Characterization Laboratory, established by the National Cancer Institute (NCI), in partnership with NIST and the Food and Drug Administration; eight university-based Centers of Cancer Nanotechnology Excellence, established under the NCI's Alliance for Nanotechnology in Cancer initiative; and four university-based centers, established by the National Heart, Lung, and Blood Institute under its Program of Excellence in Nanotechnology.
- The Department of Defense supports two university-based nanotechnology research centers, as well as the Institute for Nanoscience at the Naval Research Laboratory.
- NASA has established three centers under its University Research, Engineering, and Technology Institute program.
- The Department of Energy has established five Nanoscale Science Research Centers (NSRCs) co-located with its national labs.
- NIST has established a Center for Nanoscale Science and Technology (CNST).
- NIOSH has established a Nanotechnology Research Center to conduct research into the application of nanoparticles and nanomaterials in occupational safety and health and the implications of nanoparticles and nanomaterials for work-related injury and illness.

[65] In addition, 18 other Materials Research Science and Engineering Centers conduct nanotechnology-related research as part of their overall efforts.

Many of the centers are designated as user facilities and are available to researchers not located at the center. User facilities are designed to allow outside researchers to take advantage of facilities, equipment, tools, and expertise. These shared resources provide researchers the opportunity to conduct research, characterize materials, and test products using equipment and facilities that their individual companies, universities, or organizations could not afford to acquire, support, or maintain. Conditions for user access vary by facility and agency. In general, users are not charged for pre-competitive, non-proprietary work leading to publication, and are charged on a cost-recovery basis for proprietary work. In some cases, the user facilities are located at federal government laboratories (e.g. the Department of Energy's five NSRCs, and the NIST CNST); other user facilities are located at universities and supported with federal funds (e.g. NSF's 13 university-based centers in the National Nanotechnology Infrastructure Network (NNIN)).

As mentioned earlier, the 21st Century Nanotechnology R&D Act of 2003 directed the establishment of two centers, the American Nanotechnology Preparedness Center and the Center for Nanomaterials Manufacturing. According to the NSET subcommittee, the requirement to establish the American Nanotechnology Preparedness Center was met by NSF's establishment of the Network for Nanotechnology in Society, comprised of centers at the University of California, Santa Barbara (with the participation of Harvard University and the University of South Carolina) and the University of Arizona.[66] These centers were funded under NSF's Nanoscale Science and Engineering Center (NSEC) program and did not include participation by any other NSET subcommittee agency.[67] The NSET subcommittee states that the requirement for establishing the Center for Nanomaterials Manufacturing was met by NSF's establishment of a National Nanomanufacturing Network (NNN) comprised of four NSECs. The Center for Integrated Hierarchical Manufacturing at the University of Massachusetts Amherst is the main node of the NNN.[68] The NNN NSECs were established by NSF in collaboration with DOD and NIST, but exclusively with NSF funds.[69]

Selected NNI Reports and Assessments

This section presents summaries of recent reports from the NSTC's Nanoscale Science, Engineering, and Technology Subcommittee and assessments conducted by the National Research Council and the President's Council of Advisors on Science and Technology.

Selected NNI Reports

The NNI's coordinating body, the NSTC's Nanoscale Science, Engineering, and Technology Subcommittee, produces a variety of reports that serve to inform Congress and other key stakeholders on the initiatives' current activities, investments, and priorities.

[66] Private telephone communication between CRS and NSTC staff, January 31, 2008.

[67] Private e-mail communication between CRS and NSF staff, January 31, 2008.

[68] Private telephone communication between CRS and NSTC staff, January 31, 2008.

[69] Private e-mail communication between CRS and NSF staff, January 31, 2008.

The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY2011 Budget[70]

Each year the NSET subcommittee publishes a supplement to the President's annual budget request. The FY2011 NNI budget supplement provides a more detailed look at NNI funding in the President's budget request, including a break-out of the prior, current, and requested year budgets for each PCA. The report describes proposed changes in agency R&D budgets, as well as in the balance of investments by PCA. Of particular note:

- President Obama has proposed an overall NNI budget for FY2011 of $1.762 billion, a $19.5 million (1.1%) decrease below FY2010 funding.
- Estimated funding for EHS R&D in FY2010 rose to $91.6 million, a 23.0% increase over FY2009. President Obama has requested $116.9 million for EHS R&D in FY2011, an increase of $25.3 million (27.6%) over FY2010.
- President Obama's FY2011 budget request reflected a decline in spending in several program component areas compared to FY2010 estimated funding levels, including nanomaterials, down $12.0 million (3.9%); nanoscale devices and systems, down $31.2 million (8.4%); nanoscale devices and systems, down $27.9 million (6.5%), and instrumentation research, metrology and standards, down $7.4 million (8.8%). In addition to EHS funding, other program component areas that would be increased include fundamental phenomena and processes, up $16.5 million (3.5%), major research facilities and instrumentation acquisition, up $5.7 million (2.9%), and nanomanufacturing, up $4.7 million (4.9%%).

The National Nanotechnology Strategic Plan (2007)[71]

The 21st Century Nanotechnology R&D Act of 2003 (P.L. 108-153) requires the NSTC to develop an NNI strategic plan every three years. This plan is to guide the program's activities to meet the goals, priorities, and anticipated outcomes of the participating agencies. In addition, the act requires the triennial report to address how the program intends to move results out of the laboratory and into application for the benefit of society, its plan for long-term funding for interdisciplinary R&D, and the allocation of funding for interagency projects. The 2007 strategic plan is the first to follow external assessments by the National Academies and PCAST (operating as the NNAP) and seeks to incorporate the findings of these reviews. Of particular note:

- The 2007 strategic plan includes a new chapter on "High-Impact Application Opportunities and Critical Research Needs" possibly indicating an effort on the part of the Administration to move the NNI toward more directed research with commercial and societal benefits. Much of the early NNI work has been focused on basic research and mechanisms by which such research may produce

[70] *The National Nanotechnology Initiative: FY2011 Budget & Highlights*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, February 2010, available at http://www.nano.gov/NNI_2011_budget_supplement.pdf.

[71] *The National Nanotechnology Strategic Plan*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, December 2007, available at http://www.nano.gov/NNI_Strategic_Plan_2007.pdf.

economic and societal dividends. Seven years into the NNI, the program is under increasing scrutiny to deliver the promised benefits. While the plan does not establish R&D or application targets per se, this chapter illustrates tangible benefits that may be achieved by research supported under the NNI. In addition, the plan provides a matrix that identifies which agencies have a central or supporting role in each key application area. The plan also provides a series of nanotechnology application-specific vignettes on topics such as early detection of life-threatening disease, smarter computers, more energy-efficient transportation, and energy security.

- The 2007 strategic plan split the Societal Dimensions PCA into two separate PCAs: Environmental, Health, and Safety, and Education and Societal Dimensions. This change responds to increased Congressional and public attention to EHS needs. Some critics of the NNI had raised concerns that the inclusion of investments in education and other societal dimensions in the broader category obscured and artificially inflated the perception of investments in EHS R&D.
- The 2007 strategic plan also identifies four areas of common interest across agencies that is to be the focus of future workshops: sensors and nanoelectronics, energy, fate and transport of nanomaterials, and medical and health applications.

Strategy for Nanotechnology-related Environmental, Health, and Safety Research[72]

Strategy for Nanotechnology-related Environmental, Health, and Safety Research outlines the NNI's strategy for addressing nanotechnology EHS concerns. The report outlines the process for developing a research strategy, including identification of priority needs, assessment of existing research, and analysis of strengths and weaknesses of the current portfolio of EHS-focused research. The report provides a summary and analysis of FY2006 EHS research projects using the five priority categories identified in the earlier report, *The National Nanotechnology Initiative: Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials*[73] (discussed below). The report concludes with a framework for addressing EHS research needs, including a summary and prioritization of research needs, an implementation strategy, and a discussion of interagency coordination efforts.

[72] *Strategy for Nanotechnology-related Environmental, Health, and Safety Research*, Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, February 2008, available at http://www.nano.gov/NNI_EHS_Research_Strategy.pdf.

[73] *The National Nanotechnology Initiative: Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, September 2006, available at http://www.nano.gov/NNI_EHS_research_needs.pdf.

Prioritization of Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials: An Interim Document for Public Comment[74]

This document is a follow-on to the *Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials* report (discussed below), incorporating public comments, refinements of the prioritization principles, and continued assessment of research needs. This report further identifies and defines five priorities within each of the five general categories of research needs established in the earlier document and presents the revised principles and the process used for this prioritization. The NEHI working group of the NSET subcommittee expects to use this report to evaluate the NNI's current EHS research portfolio, perform a gap analysis, and identify opportunities for interagency collaboration. The report stresses that the NSET subcommittee is "pursuing a dynamic, open, and transparent process in developing an NNI EHS research strategy" and invites continuing public input.

The National Nanotechnology Initiative: Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials[75]

This report documents the efforts of the NSET subcommittee's Nanotechnology Environmental and Health Implications (NEHI) working group to identify, prioritize, and implement research and other activities required for the responsible research and development of nanotechnology. The report is designed to help inform the research, risk assessment, and risk management activities of federal agencies and the private sector.

The report identifies priority research within five general research areas: instrumentation, metrology, and analytical methods; nanomaterials and human health; nanomaterials and the environment; health and environmental surveillance; and risk management methods.

The report identifies several next steps:

- prioritize research needs among those identified in the report;
- evaluate in greater detail the current NNI EHS research portfolio;
- perform a "gap analysis" of the NNI EHS research compared to the prioritized needs;
- coordinate and facilitate among the NNI agencies' research programs to address priorities; and
- establish a process for periodic review of progress and for updating research needs and priorities.

[74] Prioritization of Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials: An Interim Document for Public Comment, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, August 2007, available at http://www.nano.gov/Prioritization_EHS_Research_Needs_Engineered_Nanoscale_Materials.pdf.

[75] *The National Nanotechnology Initiative: Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials*, Nanoscale Science, Engineering, and Technology Subcommittee, National Science and Technology Council, The White House, September 2006, available at http://www.nano.gov/NNI_EHS_research_needs.pdf.

The report concludes that conducting EHS research in parallel with the development of nanomaterials and their applications will help to ensure the full, safe, and responsible realization of the promise of nanotechnology, and that coordination of research activities among NNI-participating agencies, as well as with industry and other governments, is necessary to expedite progress. In contrast, some NGOs have asserted the need for EHS research to precede the development of nanomaterials and nanotechnology applications.

Selected NNI Assessments

The 21st Century Nanotechnology R&D Act of 2003 (P.L. 108-153) requires periodic external reviews of the National Nanotechnology Program (NNP) by the National Research Council, an arm of the National Academies,[76] and the National Nanotechnology Advisory Panel (NNAP).[77] In general, these reviews concluded that the NNI has been successful so far and that its efforts are important to future U.S. technological leadership and commercial competitiveness. Both reports emphasize that much nanotechnology research is still in its very early stages and caution against expecting too much in the near term from this nascent technology. The reports also laud the cooperative efforts between the NNI and stakeholders in academia and industry and encourage increased interactions with industry, state and local economic developers, and, where appropriate, international partners.

The National Nanotechnology Initiative: Second Assessment and Recommendations of the National Nanotechnology Advisory Panel, President's Council of Advisors on Science and Technology[78]

This report presents the findings of the second review of the NNI by the President's Council of Advisors on Science and Technology's, acting as the National Nanotechnology Advisory Panel, as mandated by the 21st Century Nanotechnology R&D Act of 2003. PCAST submitted its first report to the President on May 16, 2005, titled *The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel*.

As in earlier reports by PCAST and the National Research Council, this report concludes that the United States remains a leader in nanotechnology, though it recognizes the successful development of other nations' nanotechnology research capabilities. The PCAST concluded that the NNI's approach to addressing EHS research was "sound" and found proposals for a separate agency or office devoted to nanotechnology EHS research or to set aside a particular percentage of NNI funding for EHS research to be "misguided" and potentially counterproductive as resources may be directed away from research "on beneficial applications and on risk." The panel

[76] The National Research Council, the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine are part of a private, non-profit institution established under a congressional charter. They are collectively referred to as the National Academies.

[77] P.L. 108-153 directs the President to "establish or designate a National Nanotechnology Advisory Panel." In July 2004, President Bush designated the President's Council of Advisors on Science and Technology to serve as the NNAP by issuing Executive Order 13349, *Amending Executive Order 13226 To Designate the President's Council of Advisors on Science and Technology To Serve as the National Nanotechnology Advisory Panel*.

[78] The National Nanotechnology Initiative: Second Assessment and Recommendations of the National Nanotechnology Advisory Panel, President's Council of Advisors on Science and Technology, May 2005, available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST-NNAP-NNI-Assessment-2008.pdf.

also concluded that nanotechnology does not raise ethical concerns unique from those accompanying other technological advances. The PCAST also concluded that the NNI is a "highly successful model for an interagency program" describing it as "well organized and well managed."

Recommendations

The report made six broad recommendations for further strengthening the NNI, supported by more specific actions. They are:

PCAST recommendation:

> Maintaining the world-class R&D infrastructure and strong interagency coordination created under the NNI is essential to achieving broad societal benefits from nanotechnology innovation.

Some specific PCAST recommendations include continuing support for NNI multidisciplinary centers, networks and user facilities; improving coordination within agencies that have several operating divisions; and strengthening the participation of the Departments of Commerce, Education, and Labor to address education, training, market assessment, and standards development challenges related to nanotechnology.

PCAST recommendation:

> Progress across the breadth of NNI-supported R&D critically depends upon the development and implementation of standards for nanomaterial identification, characterization, and risk assessment.

In this regard, PCAST specifically recommended that federal agencies participate in the development of voluntary consensus-based standards; develop materials and analytical standards for nanotechnology EHS research; and work towards development of data sets of physical and chemical properties of nanomaterials.

PCAST recommendation:

> Nanotechnology innovation through to commercialization depends on maintaining and strengthening cross-sector collaborations and cross-fertilization of technology development and business development expertise.

Specifically, PCAST recommended expansion of efforts to assess national and international innovation and commercialization activities led by the Department of Commerce; expanded partnering between NNI multidisciplinary centers and economic development organizations; and educated more nanotechnology scientists and engineers to become entrepreneurs and skilled technology workers.

PCAST recommendation:

> Nanotechnology research must be strategically guided, integrated, and coordinated across agencies, sectors, and countries, and include balanced assessment of risks and benefits in the context of specific, real-world applications.

Among the specific PCAST recommendations: improving coordination of federal EHS research efforts with industry and international stakeholders; preventing the segregation of research focused on EHS implications of nanotechnology from research focused on applications; continuing interagency collaboration on EHS research and mission-focused research; and distributing nonproprietary information about the properties of nanomaterials.

PCAST recommendation:

> Research on the societal and ethical aspects of nanotechnology should both be integrated with technical R&D and take place in the context of broader societal and ethical leadership.

PCAST recommendation:

> Public perception of and expectations related to nanotechnology should be informed based on sound science and balanced assessment of risks and benefits (known and anticipated) of specific innovations and their implications for society.

PCAST recommended that the NNI more clearly demonstrate to the public the value of nanotechnology and NNI-supported R&D, calling for a more explicit and direct outreach approach to better inform and engage policymakers, stakeholders, and the general public. In addition PCAST recommended that NNI agencies should provided additional funding to the NNCO to support coordination among NNI agencies to enhance their agency-specific communication efforts.

Addendum to the National Nanotechnology Initiative: Second Assessment and Recommendations of the National Nanotechnology Advisory Panel, President's Council of Advisors on Science and Technology[79]

PCAST submitted an addendum to its second assessment of the NNI in July 2008, providing an assessment of *The National Nanotechnology Initiative Strategy for Nanotechnology-Related Environmental, Health, and Safety Research.* The PCAST letter reaffirmed its judgment (as stated in its second assessment of the NNI) of the NNI's approach to EHS research as "fundamentally sound in terms of strategic priorities as well as focus on and extent of collaboration across agencies, with industry, and particularly with international stakeholders." PCAST found the NNI's strategic approach to be "quite thorough and robust," and stated that the NSET subcommittee's NEHI working group

> remains the best locus of coordination and authoritative advisory capability for the participating agencies in implementing the government-wide nanotechnology EHS research strategy that cuts across agency and disciplinary lines.[80]

PCAST made six recommendations with respect to the NNI's EHS research strategy. First, PCAST recommended that an assessment of the federal nanotechnology EHS portfolio and gap

[79] *Addendum to The National Nanotechnology Initiative: Second Assessment and Recommendations of the National Nanotechnology Advisory Panel*, President's Council of Advisors on Science and Technology, May 2005, available at National Research Council, 2006, available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST-Addendum-Letter.pdf.

[80] Ibid.

analysis be performed once every three years noting that such a timetable would support the triennial reviews of PCAST and the NRC. Second, it proposed increased collaboration with industry and other countries to fill identified research gaps. Third, PCAST recommended that the NNI encourage its supported researchers to report on analytical methodologies used in their research to facilitate development of best practices for risk assessment and characterization. Fourth, PCAST stated that the NNI should promote broad and practical use of EHS findings in defining responsible use of nanotechnology in research, manufacturing, and commercial applications. Fifth, PCAST called for increased funding for exposure assessment in the context of manufacturing and disposal of nanomaterials and products incorporating relevant quantities of nanomaterials. Sixth, PCAST recommended that the NNI maintain and strengthen agency support and coordination efforts through the NSET subcommittee and the NEHI working group, specifically calling for

> all agencies that fund or conduct research on nanomaterials, as well as those agencies with charters that specifically include EHS-related activities, to directly support the NSET/NEHI data gathering and communications functions.

A Matter of Size: Triennial Review of the National Nanotechnology Initiative[81]

This 2006 report presents the findings of the National Research Council's (NRC) first triennial review mandated by the 21st Century Nanotechnology R&D Act of 2003.

The NRC study concluded that the NNI has been successful in coordinating nanoscale efforts and interests across the federal government, in catalyzing cooperative R&D across a variety of scientific and engineering disciplines, and in opening a host of new scientific opportunities through its infrastructure and R&D investments. The NRC attributed much of this success to effective communication and coordination by the NSET subcommittee and the NNCO.

Recommendations

Here are the recommendations made by the NRC followed by a discussion of each.

NRC recommendation:

> the federal government [should] sustain investments in a manner that balances the pursuit of shorter-term goals with support for longer-term R&D and that ensures a robust supporting infrastructure, broadly defined. Supporting long-term research effectively will require making new funds available that do not come at the expense of much-needed ongoing investment in U.S. physical sciences and engineering research.

President Bush has expressed support for increasing federal R&D funding for the physical sciences and engineering, most notably in his American Competitiveness Initiative which includes nanotechnology investments. Yet, as Federal non-discretionary spending growth increases pressure on federal discretionary spending, finding new funds to support long-term nanotechnology research may need to come from other scientific disciplines.

[81] *A Matter of Size: Triennial Review of the National Nanotechnology Initiative*, National Research Council, 2006, available at http://books.nap.edu/catalog.php?record_id=11752.

NRC recommendation:

> the federal government [should] establish an independent advisory panel with specific operational expertise in nanoscale science and engineering; management of research centers, facilities, and partnerships; and interdisciplinary collaboration to facilitate cutting-edge research on and effective and responsible development of nanotechnology.

In July 2004, President George W. Bush implemented the provision of the 21st Century Nanotechnology Research and Development Act to "establish or designate a National Nanotechnology Advisory Panel" by issuing Executive Order 13349, which amends Executive Order 13226, designating the President's Council of Advisors on Science and Technology to serve as the NNAP.

The NRC's recommendation suggests that the President's designation of PCAST to serve as the legislatively mandated National Nanotechnology Advisory Panel is not fully adequate. Critics of the use of PCAST to serve as the NNAP maintain that the scope and depth of expertise needed to provide effective guidance on the NNI requires an independent panel of people with nanotechnology- and interdisciplinary-specific expertise and an undivided focus. Supporters of the use of PCAST for this function assert that a single advisory panel provides an integrated perspective, reduces unnecessary cost and management burdens, and that expertise can be added to the panel or accessed through non-member technical advisory groups.

NRC recommendation:

> federal agencies participating in the NNI, in consultation with the NNCO and the Office of Management and Budget, should continue to develop and enhance means for consistent tracking and reporting of funds requested, authorized, and expended annually. The current set of PCAs provides an appropriate initial template for such tracking.

It is difficult to assess and track funding for specific purposes within the NNI because the initiative is not centrally funded and operated. The NNI budget is an aggregation of the nanotechnology-related activities of the participating federal agencies. Congress funds the NNI-related R&D on an agency-by-agency basis, with responsibilities crossing many authorizing committees and appropriations subcommittees. Thus, while it is relatively straightforward to quantify an agency's nanotechnology budget, tracking all NNI investments related to a particular activity—EHS-related research, for example—is much more difficult. The PCAs serve to provide such a tracking mechanism. In addition, according to the 2007 *National Nanotechnology Initiative Strategic Plan*, the division of the Societal Dimensions PCA into two PCAs—Environmental, Health, and Safety; and Educational and Societal Dimensions—is intended to better understand and manage the NNI investment. Such a change indicates a level of flexibility that may enable the executive branch and Congress to more effectively manage and balance investments in discrete areas of the NNI.

NRC recommendation:

> the NSET Subcommittee [should] carry out or commission a study on the feasibility of developing metrics to quantify the return to the U.S. economy from the federal investment in nanotechnology R&D. The study should draw on the Department of Commerce's expertise in economic analysis and its existing ability to poll U.S. industry. Among the activities for which metrics should be developed and relevant data collected are technology transfer and commercial development of nanotechnology.

Few efforts have been made within the federal government to understand the economic impacts of the nation's investments in the NNI. Identification and tracking of data that could serve as an indicator of success in commercializing nanotechnology research or the effects on U.S. job creation or retention has not been formalized. To the extent that federal assessments of the economic contribution of and/or potential for nanotechnology products have occurred, they have not been performed with analytical rigor. Although the Commerce Department retains its economic analysis expertise, resident primarily in the Economics and Statistics Administration's Bureau of Economic Analysis, the Department's Technology Administration, which led Commerce's NNI activities and had government-wide responsibilities for technology transfer activities, was eliminated in August 2007.[82] Prior to its elimination, the Technology Administration contracted for two studies that could contribute to addressing this NRC recommendation: an analysis of barriers to nanotechnology commercialization performed by the University of Illinois at Springfield, and an analysis of innovation metrics conducted by the Alliance for Science and Technology Research in America (ASTRA). These reports are publicly available at Commerce Department websites.[83]

NRC recommendation:

> research on the environmental, health, and safety effects of nanotechnology [should] be expanded. Assessing the effects of engineered nanomaterials on public health and the environment requires that the research conducted be well-defined and reproducible, and that effective methods be developed and applied to (1) estimate the exposure of humans, wildlife, and other ecological receptors to source material; (2) assess effects on human health and ecosystems of both occupational and environmental exposure; and (3) characterize, assess, and manage the risks associated with exposure.

While the NRC asserts the need for additional EHS research, it does not quantify how much more is needed. Clayton Teague, director of the NNCO, has testified that the current level of investment in EHS research is adequate.[84] Many critics from academia, industry, and non-profit organizations have argued strongly that the NNI needs a greater level of investment in EHS research.[85] These critics argue from a variety of perspectives, including the need to:

- protect workers, human health, and the environment;
- create public faith and confidence in the safety of nanotechnology products;
- prevent a problem with one specific nanotechnology product from resulting in a loss of public support for all nanotechnology R&D; and
- create a predictable and stable regulatory environment.

This last factor is deemed by some as critical to fostering future nanotechnology investments.

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[82] The Technology Administration was eliminated in the America COMPETES Act (P.L. 110-69).

[83] *Barriers to Nanotechnology Commercialization*, College of Business Management, University of Illinois at Springfield, September 2007, available at http://www.osec.doc.gov/Report-Barriers%20to%20Nanotechnology%20Commercialization.pdf *Innovation Vital Signs Project*, Alliance for Science and Technology Research in America, July 2007. http://www.ntis.gov/ta_reports/Report-InnovationVitalSigns.pdf.

[84] Testimony of Clayton Teague, director of the NNCO, hearing, "Environmental and Safety Impacts of Nanotechnology: What Research is Needed?" House Committee on Science, November 17, 2005. http://commdocs.house.gov/committees/science/hsy24464.000/hsy24464_0.HTM

[85] Ibid.

NRC recommendation:

> the NSET Subcommittee [should] create a working group on education and the workforce that engages the Department of Education and Department of Labor as active participants.

The NSET subcommittee has sought, with limited success, greater involvement of the Departments of Education and Labor in the subcommittee's activities. An NSET subcommittee working group on education and the workforce has not yet been established.

With advocates promising the creation of many new jobs—some assert millions—as a result of global nanotechnology investments, some have expressed concern that the country must prepare students for nanotechnology research, engineering, and production jobs.[86] Assessing which industries are likely to create such jobs, which skills will be needed, and in what timeframe are key challenges. If workers with nanotechnology-specific skills are needed and no workers are available domestically (U.S. citizens, resident aliens, or those in the United States on work visas), potential employers may opt to establish or move operations outside the United States to tap workers with those skills abroad. Conversely, if students are trained for jobs that do not emerge or do not emerge in the same timeframe as students are entering the job market, this investment is lost. In addition, potential students may be discouraged from pursuing future nanotechnology-related studies. Close coordination among the Departments of Commerce, Education, and Labor might help to align federal education and training efforts better with the labor market for nanotechnology workers.

The 21st Century Nanotechnology R&D Act also directed the NRC to address two other issues in its first triennial report: Is molecular self assembly feasible for manufacturing of materials and devices at the nanoscale? And, what are the needs for standards, guidelines, or strategies for ensuring the responsible development of nanotechnology?

Molecular Self-Assembly

Self-assembly is the process by which components (atoms, molecules, or more complex structures) form, without external control or direction, an organized structure. For example, water molecules dispersed in air in cold temperatures can self-assemble to form snowflakes. Our bodies act as self-assemblers, producing a variety of cells as needed (e.g. to repair a damage to the skin or produce new blood cells from added nutrients).

To what extent can molecular self-assembly be used as a tool for nanomanufacturing? On this issue, the NRC concluded that molecular self-assembly is feasible for the manufacture of simple materials and devices. However, for the manufacture of more sophisticated materials and devices, including complex objects produced in large quantities, the NRC found it unlikely that simple self-assembly processes will yield the desired results. One major barrier cited is the probability of error during assembly as a result of the systems' complexity.

[86] Phillip J. Bond, Under Secretary for Technology, U.S. Department of Commerce, remarks, "Nanotechnology: Economic Opportunities, Societal and Ethical Challenges," NanoCommerce 2003, December 9, 2003. http://www.technology.gov/Speeches/PJB_031209.htm *Sizing Nanotechnology's Value Chain*, Lux Research, October 2004.

Standards, Guidelines, and Strategies for Ensuring Responsible Development of Nanotechnology

The NRC concluded that it is not possible yet to make a rigorous assessment of the level of environmental and health risks posed by engineered nanomaterials and called for further development of risk assessment protocols. The NRC report also stated that the need for more EHS data requires an expanded research effort to complement dialog on these issues. In addition, until reproducible and well-characterized EHS data are available to inform the development of rigorous risk-based guidelines and best practices, the NRC found it prudent to recommend use of precautionary measures to protect the health and safety of workers, the public, and the environment. The NRC report also stressed that addressing the ethical and societal impacts of nanotechnology will require an integrated approach among scientists, engineers, social scientists, toxicologists, policymakers, and the public.

The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel, President's Council of Advisors on Science and Technology[87]

This report presents the findings of the first biennial review of the NNI by the President's Council of Advisors on Science and Technology's, acting as the National Nanotechnology Advisory Panel, as mandated by the 21st Century Nanotechnology R&D Act of 2003. The PCAST report finds that the United States is the acknowledged leader in nanotechnology R&D, but the U.S. leadership position is under increasing competitive pressure from growing public and private investments around the world. The report states that the federal investment in the NNI has been well-spent, the United States is well-positioned to maintain global leadership going forward, and continued robust funding is important for long-term U.S. economic well-being and national security. This assessment of the U.S. leadership position is founded not on sales, growth, or market share of commercial products—common measures of global competitiveness for established products—but rather on metrics that may serve as early indicators of potential innovation, such as the U.S. share of scientific publications and patents. The use of such metrics may not be universally accepted as predictive of leadership position. Technological leadership—or even leadership in innovation—does not ensure that the economic benefits from such leadership will accrue to the United States. Companies may choose to manufacture products or conduct other value-added activities outside the United States. If the assessment of national competitiveness is expanded to include the value-added activities and jobs generated or retained within the United States, then the metrics for assessing leadership might change.

The PCAST report acknowledges that there are potential environmental and health risks associated with nanotechnology, but finds that the NNI is directing appropriate attention and adequate resources to the research that will ensure the protection of the public and the environment. Nanotechnology products should not be immune from regulation, according to the report, but such regulation must be rational and based on science, not on perceived fears. The PCAST report states that strong communication exists among the NNI agencies responsible for research and regulation. The PCAST report contains four recommendations for the NNI:

[87] The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel, President's Council of Advisors on Science and Technology, May 2005, available at http://www.nano.gov/html/res/FINAL_PCAST_NANO_REPORT.pdf.

PCAST recommendation:

> To further facilitate technology transfer from the lab to the marketplace, the NNI should expand its interaction with industry, increase federal-state coordination, and improve knowledge management of and access to NNI assets, such as user facilities and instrumentation.

The NSET subcommittee's National Innovation and Liaison with Industry (NILI) working group was established to facilitate NNI interactions with industry, and with state and local nanotechnology initiatives. The NILI working group's limited resources and agency participation have hindered its ability to conduct more extensive and sustained outreach.[88] Due to the structure and resource allocation of the NNI, the initiative's engagements with industry and with state and local initiatives are largely limited to single agency or laboratory interactions and to public engagement activities, such as speeches and information on the NNI website.[89]

PCAST recommendation:

> The NNI should continue its efforts to understand the possible toxicological effects of nanotechnology and where harmful human or environmental effects are proven, pertinent federal agencies should apply appropriate regulatory mechanisms. There should be strong interagency and international collaboration on this issue to eliminate unnecessary duplication of research efforts and to ensure wide dissemination of information. Since exposure to nanomaterials is most likely to occur during the manufacturing process, research on potential hazards associated with workplace exposure must be given the highest priority.

With respect to collaboration on EHS issues, the NSET subcommittee's National Environmental and Health Implications (NEHI) working group is the primary EHS coordination mechanism for participating NNI agencies. The Global Issues in Nanotechnology (GIN) working group works with the NEHI working group on international collaboration on EHS issues. The NIOSH has published several documents addressing concerns about workplace exposure to nanoparticles. *Approaches to Safe Nanotechnology: An Information Exchange With NIOSH* was intended to provide the best currently available knowledge on nanoparticle toxicity and control and to solicit input from the stakeholder community.[90] *Progress Toward Safe Nanotechnology in the Workplace* details the work of NIOSH's Nanotechnology Research Center from 2004 through 2006.[91] In December 2007, NIOSH released interim guidance concerning the medical screening of workers potentially exposed to engineered nanoparticles during the manufacture and industrial use of nanomaterials. The NIOSH says that the document is intended to "generate discussion, fill the current knowledge gap, and provide interim recommendations until further scientific information becomes available."[92] The NIOSH is currently seeking public comment on this guidance.

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[88] Private telephone and e-mail communication with Sean Murdock, executive director of the NanoBusiness Alliance, February 4, 2008.

[89] Ibid.

[90] *Approaches to Safe Nanotechnology: An Information Exchange with NIOSH*, National Institute for Occupational Safety and Health, July 2006.

[91] *Progress Toward Safe Nanotechnology in the Workplace*, National Institute for Occupational Safety and Health, June 2007.

[92] *NIOSH Update: NIOSH Draft Offers Interim Guidance on Medical Screening of Workers Potentially Exposed to Engineered Nanoparticles*, National Institute for Occupational Safety and Health, December 13, 2007.

With respect to regulatory issues associated with nanotechnology, see CRS Report RL34332, *Engineered Nanoscale Materials and Derivative Products: Regulatory Challenges*, by Linda-Jo Schierow.

PCAST recommendation:

> The NNI should establish relationships with the Department of Education and Department of Labor to develop education and training systems to support the Nation's technical proficiency in areas related to nanotechnology.

The PCAST report's recommendation is similar to the recommendation made by the NRC and is discussed earlier in this paper.

PCAST recommendation:

> The NNI must support research aimed at understanding the societal implications of nanotechnology—including ethical, economic and legal implications—and must actively work to inform the public about nanotechnology. The NNI should continue to confront societal issues in an open, straightforward, and science-based manner.

Some critics of the NNI hold deep reservations about the ethical, economic, and legal implications of nanotechnology. Some of these concerns are common to many technologies, such as the allocation of risk and benefit during manufacturing. For example, a neighborhood located near a production facility may bear risks associated with exposure to the byproducts (or products) of manufacturing, while gaining few of the benefits. Concerns about possible adverse effects of nanoscale particles on human health and the environment resulting from their small particle size and unique characteristics may result in increased attention to such costs and benefits with respect to nanoscale material production. Currently, nanotechnology EHS risks are unknown and may be acute or pose no more risk than other manufacturing processes.

Privacy rights are another issue associated with the products of nanotechnology. Nanotechnology may enable the production of highly sensitive, inexpensive sensors that could be deployed ubiquitously in commercial and public settings. While these sensors may allow check-out-free purchases from stores, or monitor the environment for toxic substances, critics argue that they could also impinge on the privacy rights of individuals if, for example, the sensors could detect chemicals related to the use of tobacco, alcohol, or illegal substances without the permission of the individual. Such information might be later applied in law enforcement, life insurance, health insurance, or employment decisions.[93] Others express concern that the economically disadvantaged and less educated—both individuals and nations—might be unable to take part in the benefits that nanotechnology products could offer.[94]

On the legal front, innovations in nanotechnology are already presenting unique challenges to the U.S. Patent and Trademark (USPTO). For example, U.S. case law generally prohibits patenting where the sole element of novelty is a change in size, the characteristic most obviously associated

[93] Moore, Fiona M., "Implications of Nanotechnology Applications: Using Genetics as a Lesson," *Health Law Review*, Vol. 10, No. 3, 2002. http://www.law.ualberta.ca/centres/hli/pdfs/hlr/v10_3/10.3moorefrm.pdf

[94] Smith, Richard H.,"Social, Ethical, and Legal Implications of Nanotechnology," *Societal Implications of Nanoscience and Nanotechnology* (The Netherlands:Kluwer Academic Publishers, 2001).

with nanotechnology.[95] In addition, many nanotechnology innovations involve multiple disciplines. Since the USPTO structure for examining patents is discipline-based, an examiner may not have all of the requisite expertise for the examination, affecting both their ability to conduct the examination, and the speed at which it can be done. USPTO also has acknowledged the need to accelerate the speed of nanotechnology-related patent applications. According to John Doll, Commissioner of Patents, the agency is hampered in its ability to recruit and retain patent examiners with the requisite skills to handle nanotechnology patents given the "more generous offers [patent examiners get] from the private sector."[96] Doll said that efforts have been made to improve hiring and retention at USPTO, and that a new processes has been established allowing an accelerated examination of applications.[97]

Selected Nanotechnology Legislation in the 111th Congress

Title I, Subtitle A, H.R. 5116—National Nanotechnology Initiative Amendments Act of 2010

The provisions of Title I, Subtitle A of H.R. 5116, the National Nanotechnology Initiative Amendments Act of 2010, are nearly identical to H.R. 554 (see "H.R. 554—National Nanotechnology Initiative Amendments Act of 2009" below). H.R. 5116 changes the name of the act from the "National Nanotechnology Initiative Amendments Act of 2009," to "National Nanotechnology Initiative Amendments Act of 2010," and removes the term "interdisciplinary" from a provision establishing "green nanotechnology" research centers.

H.R. 554—National Nanotechnology Initiative Amendments Act of 2009

H.R. 554, the National Nanotechnology Initiative Amendments Act of 2009, was introduced on January 15, 2009, and passed by the House of Representatives on February 11, 2009. The bill was referred to the Senate Commerce, Science, and Transportation Committee on February 12, 2009. The purpose of the bill is to authorize activities for support of nanotechnology research and development and for other purposes. Among its provisions, the bill would amend the 21st Century Nanotechnology Research and Development Act of 2003 to:

- require the NSTC triennial strategic plan to include near-term and long-term objectives, the anticipated timeframe for achieving near-term objectives, and metrics for assessing progress; cooperative and collaborative activities in R&D and technology transition supported by the states; and proposed research in areas of national priority;

[95] *Nanotechnology Patents: Issues for Nanotechnology Inventions*, Dorsey and Whitney, LLP, May 9, 2005.

[96] Doll, John, Commissioner of Patents, U.S. Patent and Trademark Office, Letter to the Editor, *Small Times*, April 23, 2007. http://www.smalltimes.com/Articles/Article_Display.cfm?ARTICLE_ID=290818&p=109

[97] Ibid.

- require the NSTC annual nanotechnology report supplementing the President's budget request to include a breakout of spending for the development and acquisition of research facilities and instrumentation for each program component area, and a breakout of spending on all activities related to ethical, legal, environmental, and societal implications;
- direct NNP agencies to support the activities of committees involved in the development of standards for nanotechnology and allow agencies to reimburse the travel costs of scientists and engineers who participate in activities of such committees;
- direct the agencies to fund the National Nanotechnology Coordination Office, and to do so in proportion to each agency's share of the previous year's NNP budget;
- require the NNCO to develop and maintain a publicly accessible database of projects funded under the Environmental, Health, and Safety, the Education and Societal Dimensions, and the Nanomanufacturing program component areas;
- require the NNCO to develop, maintain, and publicize information on nanotechnology facilities supported by the NNP, including at a minimum the terms and conditions for the use of each facility, a description of the capabilities of the instruments and equipment available for use at the facility, and a description of the technical support available to assist users of the facility;
- require the establishment of a National Nanotechnology Advisory Panel (NNAP) "as a distinct entity." Currently, under the provisions of presidential Executive Order 13349, the President's Council of Advisors on Science and Technology serves as the NNAP;[98]
- direct the NNCO to enter into an arrangement with the National Research Council to conduct a triennial review of the NNP, and authorizes funds for FY2010, FY2011, and FY2012; and
- define nanotechnology as "the science and technology that will enable one to understand, measure, manipulate, and manufacture at the nanoscale, aimed at creating materials, devices, and systems with fundamentally new properties or functions," and define nanoscale as "one or more dimensions of between approximately 1 and 100 nanometers."

In addition, the bill would:

- require the designation of a White House Office of Science and Technology Policy associate director to serve as the "Coordinator for Societal Dimensions of Nanotechnology" and would charge the coordinator with convening and chairing a panel of federal agency representatives and others to develop, maintain, implement, and monitor an annual EHS research plan that includes, among other things, standards related to nanotechnology nomenclature; standards for methods and procedures for detecting, measuring, monitoring, sampling, and testing engineered nanoscale materials for environmental, health, and safety impacts; and standard reference materials for EHS testing;

[98] Executive Order 13349 is available at http://edocket.access.gpo.gov/cfr_2005/janqtr/3CFR13349.htm.

- require the National Science Foundation to provide grants to establish Nanotechnology Education Partnerships to recruit and help prepare secondary school students to pursue postsecondary level courses of instruction in nanotechnology;
- direct the NSTC to establish an Education Working Group under the NSET Subcommittee to coordinate, prioritize, and plan NNP educational activities;
- direct certain NNP agencies to provide companies access to their supported facilities to assist in the development of prototypes of nanoscale products, devices, or processes for determining proof of concept;
- direct NNP agencies to encourage nanotechnology-related submissions to their Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs;
- direct NIST to encourage nanotechnology-related submissions to its Technology Innovation Program (TIP), and directs the TIP advisory Board to provide advice to NIST to accomplish this, and to provide an assessment of the adequacy of TIP resources allocated to nanotechnology related projects;
- direct the NSTC to actively pursue industry liaison groups for all industries;
- direct the NNP to coordinate and leverage federal investments with nanotechnology research, development, and technology transition initiatives supported by the States;
- direct the NNP to support nanotechnology R&D activities directed toward application areas that have the potential for significant contributions to national economic competitiveness and for other significant societal benefits, such as nano-electronics, energy efficiency, health care, and water remediation and purification;
- direct the NNP to support research on the development of instrumentation and tools required for the rapid characterization of nanoscale materials and for monitoring of nanoscale manufacturing processes, and to support approaches and techniques for scaling the synthesis of new nanoscale materials to achieve industrial-level production rates; and
- direct certain NNP-supported interdisciplinary research centers to support research on methods and approaches to environmentally benign nanoscale products and nanoscale manufacturing processes, as well as related technology transfer and education activities.

S. 1482—National Nanotechnology Amendments Act of 2009

S. 1482, the National Nanotechnology Amendments Act of 2009, was introduced on July 21, 2009, and referred to the Senate Commerce, Science, and Transportation Committee. The purpose of the bill is to reauthorize the 21st Century Nanotechnology Research and Development Act and to expand the scope of the National Nanotechnology Program (NNP).

Among its provisions, the bill:

- requires the NNP to solicit and draw upon the perspectives of the industrial community to promote the rapid commercial development of nanoscale-enabled devices, systems, and technologies and to coordinate research in determining the key physical and chemical characteristics of nanoparticles and nanomaterials that may pose environmental, health, and safety risks;
- requires the NNCO and other appropriate agencies and councils to issue guidance to agencies that describes a strategy for transitioning research into commercial products and technologies and how the program will coordinate or conduct research on the environmental, health, and safety issues related to nanotechnology;
- requires the NSTC triennial strategic plan to include near-term and long-term objectives, the anticipated timeframe for achieving near-term objectives, and metrics for assessing progress; cooperative and collaborative activities in R&D and technology transition supported by the states; how the NNP intends to encourage and support interdisciplinary research; and proposed research in areas of national priority;
- encourages joint interagency solicitation of grant applications in high priority, multi-disciplinary research areas;
- requires participating agencies to support the activities of the committees of standards setting bodies involved in the development of standards for nanotechnology;
- requires each participating agency to provide funds to support the work of the NNCO. Authorizes appropriations to: (1) NIST for the development of nanotechnology standards; and (2) NSF, for use by the NNCO, to develop and maintain a public information database of NNP projects in EHS; education; public outreach; ethical, legal, and other societal issues; and of nanotechnology facilities accessible for use by individuals from academia and industry;
- makes the National Nanotechnology Advisory Panel (NNAP) a distinct entity, and requires the NNAP to establish a subpanel to enable it to assess whether societal, ethical, legal, environmental, and workforce concerns are adequately addressed by the NNP;
- revises provisions for triennial external review of the NNP;
- requires the designation of a "coordinator for societal dimensions of nanotechnology," within OSTP, to convene a panel to develop a research plan, and requires the coordinator to enter into an arrangement with the National Science Board to create a report that identifies the broad goals and needs of EHS researchers;
- directs the NSTC to establish an interagency Education Working Group to coordinate, prioritize, and plan formal and informal educational activities supported under the NNP, including activities to help participants understand the EHS implications of nanotechnology;
- provides for one or more grants to establish Nanotechnology Education Partnerships to recruit and help prepare secondary school students to pursue postsecondary level courses in nanotechnology;

- requires agencies supporting nanotechnology research facilities to provide access to representatives from industry and other stakeholders for the transfer of research results or assist in developing proof-of-concept prototypes of nanoscale products, devices, or processes;
- directs NIST, in its Technology Innovation Program, and all agencies with Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, to encourage the submission of nanotechnology related grant proposals;
- sets, for the NNP, the objective of establishing industry liaison groups for all industry sectors that would benefit from nanotechnology applications;
- requires coordination and leveraging of federal investments with nanotechnology research, development, and technology transition initiatives supported by state governments;
- requires the NNP to support nanotechnology R&D in areas of national importance (e.g., economic competitiveness, energy production, water purification, agriculture, and health care; in environmental, health, and safety research on the risks of nanoparticles) and in ethical, legal, and societal issues related to nanotechnology;
- requires the NNP to support a wide array of research in support of nanomanufacturing;
- requires the director of the NNCO to review and report on nanomanufacturing research and research facilities;
- requires an NNAP review of the nanomanufacturing program component area and the capabilities of nanotechnology research facilities supported by the NNP;
- sets forth provisions regarding NNP nanoscale characterization and metrology research; and
- requires deliberative public input in the decision making processes affecting policies for the research, development, and use of nanotechnology, and authorizes $2.0 million for the NNCO to carry out this responsibility.

S. 596—Nanotechnology Innovation and Prize Competition Act of 2009

S. 596, the Nanotechnology Innovation and Prize Competition Act of 2009, was introduced on March 16, 2009, and referred to the Senate Commerce, Science, and Transportation Committee. The purpose of the bill is to establish an award program to honor achievements in nanotechnology. Under the bill, the Department of Commerce's National Institute of Standards and Technology is directed to award prizes to individuals and companies for achievement in one or more of the following areas: improvement of the environment, consistent with EPA's Twelve Principles of Green Chemistry; development of alternative energy that has the potential to lessen the dependence of the United States on fossil fuels; and/or improvement of human health, consistent with regulations promulgated by the FDA. The bill authorizes financial prizes for being the first to achieve a specific criteria, as well as recognition prizes, made as part of the previously established National Technology and Innovation Medal award program. The bill authorizes

$2,000,000 annually for the financial prizes as well as $750,000 annually for administration of the prize competitions.

H.R. 820—Nanotechnology Advancement and New Opportunities Act

H.R. 820, the Nanotechnology Advancement and New Opportunities Act, was introduced on February 3, 2009, and referred to four House committees: the Committee on Science and Technology, the Committee on Energy and Commerce, the Committee on Ways and Means, and the Committee on Homeland Security. The purpose of the bill is to ensure the development and responsible stewardship of nanotechnology. The bill would:

- establish a $100 million Nanomanufacturing Investment Partnership at the Department of Commerce to work with private investors to advance the commercialization of nanomanufacturing technologies and to increase the commercial application of federally supported research results;
- establish a 15% tax credit, taken over five years, for the purchase of up to $10 million of stock in qualified nanotechnology companies; and
- establish a grant program within the DOC to support the establishment and development of nanotechnology incubators by non-profit entities and degree-granting institutions;
- require the Director of the NNCO to prepare a report to Congress on a nanotechnology research strategy for government and industry that will ensure the development and responsible stewardship of nanotechnology;
- provide a tax credit of 50% for nanotechnology education and training expenses for businesses and individuals;
- authorize an annual appropriation of $15 million for FY2010 through FY2013 for the NSF to conduct a grant program for the development of curriculum materials for interdisciplinary nanotechnology courses at institutions of higher education;
- direct the NSF to establish, through its Advanced Technological Education program, a program to encourage manufacturing companies to enter into partnerships with occupational training centers for the development of training to support nanomanufacturing; and
- direct the Secretary of Energy to submit a report to Congress containing a strategy for increasing interaction among scientists and engineers at DOE national laboratories and the informal science education community to prepare appropriate exhibits for school age children and the general public.

In addition, the bill would amend the 21st Century Nanotechnology Research and Development Act of 2003 to:

- authorize $10 million for the NSF to establish a center for the development of computer-aided design tools for nanotechnology applications;

- authorize an annual appropriation of $30 million for the DOE to conduct a grant program for nanotechnology research to address the need for "clean, cheap, renewable energy;"
- authorize an annual appropriation of $30 million for the EPA for a grant program for nanotechnology research to address technologies for the remediation of pollution and other environmental protection technologies;
- authorize an annual appropriation of $30 million for the DHS to conduct a grant program for nanotechnology research to address the need for sensors and materials related to homeland security needs; and
- authorize an annual appropriation of $30 million for the DHHS to conduct a grant program for nanotechnology research to address health-related applications.

H.R. 2647—National Defense Authorization Act for Fiscal Year 2010

Section 242 of the National Defense Authorization Act for Fiscal Year 2010 (H.R. 2647, P.L. 111-84) amends the Department of Defense's nanotechnology reporting responsibilities to align with those required of other agencies under the 21st Century Nanotechnology Research and Development Act (P.L. 108-153). H.R. 2647 was signed into law on October 28, 2009.

S. 3117—Promote Nanotechnology in Schools Act

S. 3117, the Promote Nanotechnology in Schools Act, was introduced on March 15, 2010, and referred to the Senate Committee on Health, Education, Labor, and Pensions. The purpose of the bill is to strengthen the capacity of eligible institutions (i.e., secondary schools, community colleges, two-year and four-year institutions of higher education, and informal learning science centers) to provide instruction in nanotechnology. The bill would authorize a program at the National Science Foundation for this purpose that would offer eligible institutions grants of up to $400,000 (subject to a 25% match from non-federal sources) to assist in the purchase and maintenance of nanotechnology equipment and software, to develop and provide educational services, and to support teacher education and certification. The bill would authorize $15 million for FY2010 and "such sums as may be necessary" for FY2011 through FY 2013.

H.R. 4502—Nanotechnology Education Act

H.R. 4502, the Nanotechnology Education Act, was introduced on February 19, 2010, and referred to the House Committee on Science and Technology's Subcommittee on Research and Science Education. The purpose of the bill is to strengthen the capacity of eligible institutions (i.e., secondary schools, community colleges, four-year institutions of higher education, and informal learning science centers) to provide instruction in nanotechnology. The bill would authorize a program for this purpose at the National Science Foundation that would offer eligible institutions grants of up to $400,000 (subject to a 25% match from non-federal sources) to assist in the purchase and maintenance of nanotechnology equipment and software, to develop and provide educational services, and to support teacher education and certification. The bill would authorize $40 million for FY2011 and "such sums as may be necessary" for FY2012 through FY 2014.

S. 2942—Nanotechnology Safety Act of 2010

S. 2942, the Nanotechnology Safety Act of 2010, was introduced on January 21, 2010, and referred to the Senate Committee on Health, Education, Labor, and Pensions. The bill would require the Secretary of Health and Human Services to establish within 180 days a program for the scientific investigation of nanoscale materials included or intended for inclusion in FDA-regulated products, to address the potential toxicology of such materials, the effects of such materials on biological systems, and interaction of such materials with biological systems. The bill would authorize $25 million per year for fiscal years 2011 to 2015.

Concluding Observations

Many expect nanotechnology to bring significant economic and societal returns. The United States was the first government to launch a national-level nanotechnology program and has invested more than any other nation. As a result of this focus and these sustained investments, many experts believe that the United States enjoys a technological leadership position in nanotechnology. Other nations are investing heavily and some industrialized and emerging economies have formidable capabilities in nanotechnology. Assessments of the National Nanotechnology Initiative have concluded that the effort is well-managed and has been successful in achieving its objectives so far. However, these assessments have recognized that the NNI faces a variety of challenges in ensuring that the full promise of nanotechnology is realized and that the United States remains the global leader in nanoscale science, engineering, and technology.

Congress may choose to address some or many of the issues addressed in the body of this report in the course of deliberation on the reauthorization of the 21st Century Nanotechnology R&D Act of 2003 or, alternatively, in separate legislation.

The 21st Century Nanotechnology R&D Act's funding authorizations extended through FY2008. Action is being considered in both the House and Senate on reauthorization of the program. Possible topics for consideration in the reauthorization process include budget authorization levels for the covered agencies; R&D funding levels, priorities, and balance across the program component areas; administration and management of the NNI; translation of research results and early-stage technology into commercially viable applications; environmental, health, and safety issues; ethical, legal, and societal implications; education and training for the nanotechnology workforce; metrology, standards, and nomenclature; public understanding; and international dimensions. Consideration may also be given to the establishment of an independent review panel and to coordination of the timing for the NNAP assessment, the NRC assessment, and the NSET subcommittee's strategic plan for the NNI.

Appendix A. Selected Reports on the National Nanotechnology Initiative

Reports of the Nanoscale Science, Engineering, and Technology Subcommittee of the National Science and Technology Council

The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY2010 Budget. May 2009.

The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY2009 Budget. September 2008.

National Nanotechnology Initiative Fiscal Year 2009 Budget Summary & Highlights. February 2008

Strategy for Nanotechnology-Related Environmental, Health, and Safety Research. February 2008

The National Nanotechnology Initiative Strategic Plan. December 2007.

The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY2008 Budget. July 2007.

The National Nanotechnology Initiative: Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials. September 2006.

The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY2007 Budget. July 2006.

The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY2006 Budget. March 2005.

The National Nanotechnology Initiative Strategic Plan. December 2004.

Nanotechnology in Space Exploration. August 2004.

Nanoscience Research for Energy Needs. Report from a workshop held in March 2004.

Instrumentation and Metrology for Nanotechnology. Report from a workshop held in January 2004.

Nanotechnology: Societal Implications-Maximizing Benefits for Humanity. Report from a workshop held in December 2003.

Nanobiotechnology. Report from a workshop held in October 2003.

Regional, State, and Local Initiatives in Nanotechnology. Report from a workshop held in September-October 2003.

National Nanotechnology Initiative: Research and Development Supporting the Next Industrial Revolution, Supplement to the President's FY2004 Budget. August 2003.

Nanotechnology and the Environment. Report from a workshop held in May 2003.

National Nanotechnology Initiative: The Initiative and Its Implementation Plan, Detailed Technical Report Associated with the Supplemental Report to the President's FY2003 Budget. June 2002.

National Nanotechnology Initiative: The Initiative and Its Implementation Plan, Detailed Technical Report Associated with the Supplemental Report to the President's FY2001 Budget. July 2000.

Report of the Interagency Working Group on Nanoscience, Technology, and Engineering (NSET Subcommittee Predecessor)

Nanotechnology: Shaping the World Atom by Atom. 1999.

Agency Reports

NIOSH Update: NIOSH Draft Offers Interim Guidance on Medical Screening of Workers Potentially Exposed to Engineered Nanoparticles, National Institute for Occupational Safety and Health. December 2007.

Progress Toward Safe Nanotechnology in the Workplace, National Institute for Occupational Safety and Health. June 2007.

Approaches to Safe Nanotechnology in the Workplace, National Institute for Occupational Safety and Health. July 2006.

Nanoscale Science, Engineering, and Technology in DOE's Office of Basic Energy Sciences, U.S. Department of Energy. February 2003.

External Reviews

A Matter of Size: Triennial Review of the National Nanotechnology Initiative, National Research Council. 2006.

The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel, President's Council of Advisors on Science and Technology (acting as the National Nanotechnology Advisory Panel). May 2005.

Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative, National Research Council. June 2002.

Appendix B. List of NNI and Nanotechnology-Related Acronyms

ASTRA	Alliance for Science and Technology Research in America
CNST	Center for Nanoscale Science and Technology
CS	Committee on Science
CT	Committee on Technology
CSREES	Cooperative State Research, Education, and Extension Service
DHHS	Department of Health and Human Services
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOJ	Department of Justice
DOT	Department of Transportation
EHS	Environmental, health, and safety
ELSI	Ethical, legal, and societal implications
EPA	Environmental Protection Agency
EOP	Executive Office of the President
EPSCoR	Experimental Program to Stimulate Competitive Research
FHWA	Federal Highway Administration
GIN	Global Issues in Nanotechnology working group
ISO	International Standards Organization
IWGN	Interagency Working Group on Nanotechnology
NASA	National Aeronautics and Space Administration
NCI	National Cancer Institute
NEHI	National Environmental and Health Implications working group
NGO	Non-governmental organization
NIH	National Institutes of Health
NILI	National Innovation and Liaison with Industry working group
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
NNAP	National Nanotechnology Advisory Panel
NNCO	National Nanotechnology Coordination Office
NNI	National Nanotechnology Initiative
NNIN	National Nanotechnology Infrastructure Network
NNN	National Nanomanufacturing Network
NNP	National Nanotechnology Program

NPEC	Nanotechnology Public Engagement and Communications working group
NRC	National Research Council
NSET	Nanoscale Science, Engineering, and Technology subcommittee
NSF	National Science Foundation
NSEC	Nanoscale Science and Engineering Center
NSRC	Nanoscale Science Research Centers
NSTC	National Science and Technology Council
OECD	Organization for Economic Cooperation and Development
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
PCA	Program Component Areas
PCAST	President's Council of Advisors on Science and Technology
R&D	Research and development
SBIR	Small Business Innovation Research
STTR	Small Business Technology Transfer Research
TSA	Transportation Security Administration
USDA	U.S. Department of Agriculture
USPTO	U.S. Patent and Trademark Office

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