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Manipulating Molecules: Federal Support for Nanotechnology Research

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Summary

The Bush Administration has requested $1.277 billion for nanotechnology research for FY2007, $24 million less than the estimated $1.301billion appropriated level for FY2006. (See **Table 1**.) Nanotechnology is a newly emerging field of science where scientists and engineers are beginning to manipulate matter at the molecular and atomic levels in order to obtain materials and systems with significantly improved properties. Ten nanometers is equal to one-ten thousandths the diameter of a human hair. Proponents of this technology argue that nanotechnology will lead to a new industrial revolution in the 21st century. Scientists note that nanotechnology is still in its infancy, with large scale practical applications 10 to 30 years away. Congressional concerns include funding for the National Nanotechnology Initiative (NNI), the potential environmental and health concerns associated with the development and deployment of nanotechnology, and the need to adopt international measurement standards for nanotechnology.

Introduction

As indicated in **Table 1**, the Administration is requesting $1.277 billion for nanotechnology research in FY2007, $24 million less than the estimated $1.301 billion appropriated level for FY2006. Nanotechnology[1] is the creation and utilization of materials, devices, and systems with novel properties and functions through the control of matter atom by atom, or molecule by molecule. Such control takes place on a scale of a fraction of a nanometer to tens of nanometers. Ten nanometers is equal to one-ten thousandths the diameter of a human hair.

Academic and industry scientists working in this field contend that research in nanoscience will lead to revolutionary breakthroughs in such areas as medicine, manufacturing, materials, construction, computing, and telecommunications. Within a

[1] For purposes of this report, the term "nano" can be applied to technology, measurement, science, or other research fields. The size of an average virus is equal to one nanometer (nm).

short period of time, nanotechnology has expanded from an obscure research obsession to a worldwide scientific and industrial enterprise. According to the National Science Foundation, by 2015 nantechnology will have grown to a $1 trillion enterprise, with over 500 products sold made at the nanoscale or with engineered nanomaterials. The marriage of nano and biotechnology will likely create a whole new generation of drugs, biomedical devices, and other solutions to some of our most challenging medical problems.[2] However, according to F. Mark Modzelewski, founder of the Nano Business Alliance, what researchers can do to control and manipulate atoms and molecules is still limited. Nevertheless, despite being at the early stages of nano development, more than 1200 companies conduct nanotechnology Research and Development (R&D). They vary from startups such as Nano-Tex, a company that developed anti- wrinkle chemicals for textiles, to large corporations like General Electric and Hewlett-Packard. Recent developments in nano have helped IBM develop computer hard drives that store one hundred times more data than older models. Another company has discovered a process to develop cheaper and easier-to-use solar cells, while still another firm is utilizing nanoparticles to improve screens for phones. Medical researchers are exploring alternative methods for delivering anti-cancer drugs to specific sites, allowing doctors to kill only diseased cells while concomitantly enhancing the growth of healthy cells.[3]

In May of 2005, the President's Council of Advisors on Science and Technology (PCAST) released a report entitled, *The National Nanotechnology Initiative at Five: Assessment and Recommendations of the National Nanotechnology Advisory Panel*. Overall the advisory panel indicated that the management of the federal multi-agency initiative was well coordinated and effective. However, PCAST struck a cautionary tone by noting that increased investments by other countries had eroded the U.S. position as the global leader in nanotechnology.[4]

Nanotechnology and the Federal Role

In FY2004, the Bush Administration designated the National Nanotechnology Initiative (NNI) as a multi-agency research initiative aimed at maximizing the return on the federal investment in nanoscale R&D through coordination of funding, research, and infrastructure development activities at individual agencies. Since President Bush took office in 2001, funding for the federal NNI has increased from $454 million in FY2001 constant dollars, to an estimated $1.111 billion in FY2006, a 144% increase in real dollars. However, as indicated in **Table 1**, the Administration is requesting $1.277 billion for nanotechnology research in FY2007, a 4% decline in real dollars.

The coordination of the NNI occurs at two different levels within the federal government. With the enactment of P.L. 108-153 (The 21st Century Nanotechnology

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[2] Jane Macoubrie, *Informed Public Perceptions of Nanotechnology and Trust in the Government*, Woodrow Wilson International Center for Scholars, September 8, 2005, p. 1.

[3] David Masci, Nanotechnology, *The CQ Researcher*, June 11, 2004, vol. 14, no. 22, pp. 517-540.

[4] Candace Stuart, "President's Advisors Recommend NNI Branch Out," *Small Times*, May 19, 2005, p. 1.

Research and Development Act), the National Science and Technology Council (NSTC)[5] Committee on Technology (CT) is now responsible for setting priorities and coordinating joint research activities among the agencies participating in the NNI. The NSTC requested PCAST to conduct a review of the NNI as called for in P.L. 108-153. The NSTC Committee on Technology also directed the Nanoscale Science, Engineering and Technology (NSET) committee (consisting of the agencies involved in the NNI) to assist PCAST with its review of the NNI. Further, with the passage of the Bob Stump, National Defense Authorization Act for Fiscal Year 2003 (P.L. 107-314, Sec. 246), the NSTC is responsible for the coordination of DOD's nanotechnology activities.

At the second level the NSTC established the National Nanotechnology Coordinating Office (NNCO) in October 2000. In addition to being responsible for the day-to-day management of the NNI, the NNCO assists the Committee on Technology with identifying funding priorities, establishing budgets, and evaluating current NNI activities. The five agencies included in P. L. 108-153 are the National Science Foundation (NSF), the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), the National Institute of Standards and Technology (NIST) within the Department of Commerce (DOC), and the Environmental Protection Agency (EPA). Further, reflecting committee jurisdiction, the NNI authorization legislation does not include nanotechnology research activities in six other agencies which also fund nanotechnology research. These include the Departments of Defense (DOD), Homeland Security (DHS), Agriculture (USDA), Justice (DOJ), the National Institutes of Health (NIH), and the National Institute for Occupational Safety and Health (NIOSH).

Table 1. Estimated Funding for Nanotechnology FY2007
($ millions)

	FY2004 Enacted	FY2005 Enacted	FY2006 Estimate	FY2007 Request
NNI Total	**961**	**1,200**	**1,301**	**1,277**
NSF	254	335	344	373
DOE	203	208	207	258
NASA	37	45	50	25
DOC (NIST)	63	79	76	86
EPA	5	7	5	9
DOD	315	352	436[c]	345
DHS (TSA)[a]	1	1	2	2
USDA	1	3	2	5
NIOSH[b]	0	3	3	3
Department of Justice	2	2	1	1
HHS (NIH)	80	165	175	170

[5] The NSTC is a Cabinet-level Council, chaired by the President, which coordinates science, space, and technology and the diverse parts of the federal research and development enterprise. Membership consists of the Vice President, Assistant to the President for Science and Technology, Cabinet Secretaries, and Agency Heads with significant science and technology responsibilities, and other White House officials.

Note: Agencies in italics are included in P.L. 108-153, the National Nanotechnology Program.

a. Department of Homeland Security.
b. National Institute of Occupational Safety and Health.
c. Includes $148 million in earmarks, according to DOD.

The FY2006 Strategic Plan

After the enactment of P.L.108-153, the NSTC, Committee on Technology (CT) became responsible for developing a strategic plan for the NNI. The NSTC is required to update the plan every three years. According to the Administration, the FY2006 strategic plan articulates a vision for the NNI in which the ability to understand and control matter on the nano scale will lead to a revolution in technology and industry. The revised strategic plan focuses on four cross-cutting goals. They are:

1. Maintain a world class research and development program aimed at realizing the full potential of nanotechnology. Long-term basic research is considered essential to establishing a fundamental knowledge of nanoscale phenomena. Research activities performed by individual researchers, as well as interdisciplinary research teams, are to focus on fundamental understanding and synthesis of nanometer-size building blocks with potential breakthroughs in a number of scientific and engineering disciplines.

2. Facilitate the transfer of new technology into products for economic growth, jobs, and other public benefits. The second goal focuses on ensuring that breakthroughs in federally sponsored nanotechnology research are quickly transferred to the private sector. The strategic plan highlights a number of current mechanisms utilized by the NNI to transfer research outcomes to the private sector. They include the establishment of the NSET industry liaison group with various commercial sectors to promote the exchange of information on NNI research programs and industry needs that relate to nanotechnology

3. Develop educational resources, a skilled workforce, and supporting infrastructure and tools to advance nanotechnology. Within this goal, the NNI's primary objective is to ensure the education of the next generation of researchers and innovators. In addition, it also requires the development of a workforce with technical skills needed to work in a nano environment. Further, in addition to human resources, the government maintains a number of research user facilities outside the NNI that support nano research.

4. Support responsible development of nanotechnology. According to the strategic plan, responsible development of nanotechnology means that the federal government supports the previous three goals of the initiative, but concomitantly endorses concerns about the potential societal concerns associated with the development and deployment of nanotechnology. Nanotechnology societal dimensions include a range of issues such as equitable access to benefits arising from nanotechnology, possible health or environmental effects, and privacy concerns associated with distributed nanotechnology-based sensors.

Program Component Areas

The 21st Century Nanotechnology Research and Development Act directed the NSTC to establish Program Component Areas (PCAs), with specific priorities and technical goals, which reflect the priority goals established for the entire nanotechnology program. While the NNI goals embody the vision of the initiatives, the PCAs relate to areas of investment that are critical to accomplish the goals.[6] These areas cut across the interests and needs of the participating agencies and indicate where advancements may be enhanced through the coordination of multiple agencies. According to NSET, PCAs provides a structure by which the agencies funding R&D can better direct and coordinate their research activities.[7] The seven PCAs are: 1) Fundamental nanoscale processes, 2) Nanomaterials, 3) Nanoscale devices and systems, 4) Instrumentation research, metrology[8] and standards, 5) Manufacturing, 6) Major research facilities, and instrumentation acquisition, and 7) Social dimensions.

Congressional Issues

Nanotechnology Environmental and Health Concerns. Despite the great promise surrounding nanotechnology, questions have been raised regarding potential environmental and health concerns associated with the development and use of nanoscale materials. While nanotechnology may have the ability to make the environment cleaner, scientists acknowledge that manufacturing and use of nanomaterials could also present unique environmental concerns, since these materials represent new types of matter. A study by the Royal Society of England noted that there is no information available regarding the effects of nanoparticles on species other than humans. Consequently the Society recommended that release of nanoparticles into the atmosphere be avoided. Specifically it recommended that factories and research laboratories treat manufactured nanoparticles and nanotubes as if they were hazardous and reduce them from waste streams, as well as environmental applications such as remediation of ground water.[9]

In an initial study to examine potential health effects nanoparticles may have on aquatic animals, Dr. Eva Oberdoester, from Southern Methodist University, reported that within 48 hours, a small concentration of nanomaterials (C60, fullerenes) in an aquarium cause severe brain damage in baby fish. This result surprised many scientists because, according to John Bucher from NIH's National Institute of Environmental Health Sciences (NIEHS), the researchers thought the nanomaterial would just become part of the "muck" in the fish tank. Dr. Bucher asserted that the outcome of this experiment

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[6] The National Nanotechnology Initiative, Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY2006 Budget, p. 5.

[7] The PCAs are Fundamental nanoscale phenomena, Nano-materials, Nanodevices and systems, Instrumentation, Nano-manufacturing, Research facilities and instrumentation, and Societal dimensions.

[8] Metrology is the study of measurement.

[9] Nanoscience and Nanotechnologies: Opportunities and Uncertainties, The Royal Society, and Royal Academy of Engineering, July 2004, Summary and Recommendations, p. 5.

means that scientists need to pay more attention to this area.[10] As part of its NNI activities, the EPA is sponsoring research that will examine possible environmental concerns associated with the manufacturing and use of nanomaterials.

Nanotechnology and International Measurement Standards. While scientists around the world share research findings and attend international meetings, there are currently no internationally accepted measurement standards regarding the regulation and sale of nanotechnology products. The lack of such standards has contributed to a number of complaints related to the sale and distribution of nanomaterials. For example, a semiconductor company found that one-third of a sample of carbon nanotubes it had purchased consisted of iron left over from the production process, rendering the batch useless.[11]

To address these concerns, the American National Standards Institute (ANSI) and the British Standards Institute (BSI) met with the International Standards Organization (ISO) to prepare for an international meeting held in November of 2005. At the November meeting representatives from thirty three nations agreed to focus their initial activities in three broad topical areas for standardization consideration proposed by the BSI.[12] The three areas are: 1) General terminology for nanoscience and technology, including a definition of the terms "nano and Nomenclature";[13] 2) Metrology and Characterization; and 3) Health, Safety, and the Environment (HS&E) including impacts/risk assessment, reference standards for testing, controls, and testing methods for toxicity. Canada was selected as the convener of the Terminology and Nomenclature working group, Japan the convener the of Metrology group, and the United States the convener of the HS&E group. The countries selected as the conveners are responsible for preparing their working members for the next nanotechnology standards meeting scheduled for June of 2006. The ISO hopes to complete this first round of standards development activities by the end of this year.

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[10] "Nanoparticles Toxic in Aquatic Habitat, Study Finds," *The Washington Post*, Rick Weiss, March 29, 2004, p. A3.

[11] "Growing Nanotech Trade Hit by Questions over Quality," *Nature*, VOL 432, 16 December, 2004, p.791.

[12] The global response included countries in Europe, the Middle East, Africa, the Americas, and the Pacific-Rim.

[13] Nomenclature is a system of naming and categorizing objects in a given category.