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National Nanotechnology Investment in the FY 2011 Budget[1]

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INTRODUCTION

The emerging fields of nanoscale science, engineering, and technology—which investigate how to measure and restructure matter at the atomic and molecular levels to create materials, devices, and systems with fundamentally new properties and functions—are leading to unprecedented understanding and control over the basic building blocks and properties of all natural and manmade things. The fiscal year (FY) 2011 funding request for nanoscale science, engineering, and technology (in brief, *nanotechnology*) research and development (R&D) in 15 federal departments and agencies is **$1.76 billion** (Table I-8) reflecting a continuous growth. This investment is known as the National Nanotechnology Initiative (NNI) and began in FY 2001, inspired by a long-term vision[3] , with a budget of $494 million.[4] The NNI engages 25 federal departments and agencies (Appendix A) in strategic collaboration to accelerate the discovery, development, and deployment of nanotechnology. Because of the NNI, federal agencies have initiated major new nanotechnology R&D activities under a common vision that supports national goals and agency missions, an extensive infrastructure of nanotechnology research and education centers has been established, and participating agencies are working together to maximize the effectiveness of their individual and collective investments on society.

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[1] The chapter is available online at http://www.aaas.org/spp/rd/rdreport10/
[2] The author is Senior Advisor to the National Science Foundation (NSF) and key architect of the National Nanotechnology Initiative. Any opinions expressed in this material are those of the author and do not necessarily the views of NSF.
[3] "Nanotechnology Research Directions" (M.C. Roco, S. Williams and P. Alivisatos), Springer 1999, adopted as an official document of NSTC in 2000.
[4] See the NNI website at http://nano.gov

The NNI vision is a future in which understanding and control of matter at the nanoscale will lead to a revolution in technology and industry that benefits society. The four goals of the NNI are to: advance a world-class nanotechnology research and development program; foster the transfer of new technologies into products for commercial and public benefit; develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; and support responsible development of nanotechnology.

Table I-8 (NNI). NNI budget by agency, 2009-2011 (dollars in millions)

Agency	2009 Actual	2009 Recovery*	2010 Estimated	2011 WH Request
DOE**	332.6	293.2	372.9	423.9
NSF	408.6	101.2	417.7	401.3
HHS/NIH	342.8	73.4	360.6	382.4
DOD***	459.0	0.0	436.4	348.5
DOC/NIST	93.4	43.4	114.4	108.0
EPA	11.6	0.0	17.7	20.0
HHS/NIOSH	6.7	0.0	9.5	16.5
NASA	13.7	0.0	13.7	15.8
HHS/FDA	6.5	0.0	7.3	15.0
DHS	9.1	0.0	11.7	11.7
USDA/NIFA	9.9	0.0	10.4	8.9
USDA/FS	5.4	0.0	5.4	5.4
CPSC	0.2	0.0	0.2	2.2
DOT/FHWA	0.9	0.0	3.2	2.0
DOJ	1.2	0.0	0.0	0.0
TOTAL**	**1,701.5**	**511.3**	**1,781.1**	**1,761.6**

* Based on allocations of the American Recovery and Reinvestment Act of 2009 (P.L. 111-5) appropriations. Agencies may report additional ARRA funding for SBIR and STTR projects later, when 2009 SBIR/STTR data become available.

** Funding levels for DOE include the Office of Science, the Office of Energy Efficiency and Renewable Energy, the Office of Fossil Energy, the Office of Nuclear Energy, and the Advanced Research Projects Agency–Energy.

*** In Tables 2–4, the 2009 and 2010 DOD figures include Congressionally directed funding that is outside the NNI plan ($117 million for 2009).

**** Totals may not add, due to rounding.

Nanotechnology is transitioning its R&D focus from nanoscale components to nanosystems in 2011. While the NNI continues to fulfill the Federal role of supporting basic research, infrastructure development, and technology transfer, the proposed investments for 2011 place

renewed emphasis on accelerating the transition from basic R&D advances into innovations that support national priorities such as energy, manufacturing, healthcare, and environmental protection. Three NNI Signature Initiatives are planned (http://www.nano.gov/html/research/signature_initiatives.html): (a) Nanotechnology Applications for Solar Energy (DOE, NIST, NSF, DOD, DNI, USDA/NIFA); (b) Sustainable Nanomanufacturing (NIST, NSF, DOE, EPA, NIH); and (c) Nanoelectronics for 2020 and Beyond (NSF, DOD, NIST, DOE, DNI). The NNI is also increasing its investments in nanotechnology-related environmental, health, and safety (EHS) research by 28% as compared to estimated FY2010. As a part of this expanded EHS effort, the Food and Drug Administration and the Consumer Product Safety Commission are participating in the formal NNI budget crosscut for the first time in 2011.

The 21st Century Nanotechnology R&D Act (Public Law 108-153) authorized long-term funding levels for five agencies (NSF, DOE, NASA, NIST, and EPA), and new legislation for multiyear reauthorization is currently in preparation in Congress.

SUMMARY OF FY 2011 BUDGET REQUEST FOR NNI

The FY 2011 President's Request is approximately $1.76 billion for federal investment in nanotechnology. Approximately 65 percent of the total NNI funding supports academic research. About 25 percent of NNI funding supports R&D at government laboratories, and about 10 percent supports industry R&D of which about 6 percent for SBIR/STTR.

NNI-supported R&D is reported in eight program component areas (PCAs); the PCAs and proposed FY 2011 funding levels across all NNI agencies are as follows: (1) fundamental nanoscale phenomena and processes, $484 million; (2) nanomaterials, $342 million; (3) nanoscale devices and systems, $402 million; (4) instrumentation research, metrology, and standards for nanotechnology, $77 million; (5) nanomanufacturing, $101 million; (6) major research facilities and instrumentation acquisition, $203 million; (7) environment, health, and safety (EHS), $117 million; and (8) education and societal dimensions, $35 million.

The FY 2011 NNI budget request maintains fundamental nanoscale phenomena and processes as the largest PCA at $484 million. The Department of Energy now includes Advanced Research Projects-Energy

(ARPA-E) and increased funding for Office of Science and the Office of Energy Efficiency and Renewable Energy. The fastest growing PCAs are in the areas of EHS to $117 million and of Nanomanufacturing to $101 million.

The largest percentage increases in NNI are at agencies that have responsibilities related to EHS issues such as FDA, CPSC, NIOSH.

DEPARTMENT OF ENERGY (DOE)

In FY 2011, the total request for DOE is $424 million, including a $51 million increase over the FY 2010 estimated budget (see Table I-8). The FY 2011 request includes a substantial increase in funding for research at the nanoscale for activities related to energy conversion and storage, at the Office of Science, the Office of Energy Efficiency and Renewable Energy, the Office of Fossil Energy, the Office of Nuclear Energy, and the Advanced Research Projects Agency–Energy. The FY 2011 request includes R&D funding for all five Nanoscale Science Research Centers (NSRC). Support for fundamental scientific research on nanoscale phenomena would be by grant programs and DOE National Laboratory research efforts. The Energy Frontier Research Centers and Energy Innovation Hubs on Fuels from Sunlight will be expanded.

NATIONAL SCIENCE FOUNDATION (NSF)

The FY 2011 request for NSF nanotechnology activities is approximately $401 million (see Table 1). NSF has provided $108 million in additional support for nanotechnology from ARRA funds in FY 2009 and FY 2010 ($35 million by the Directorate for Engineering and $73 million by the Directorate for Mathematical and Physical Sciences).

Table 1. NSF Directorate Budgets for NNI funding

National Nanotechnology Initiative Funding
(Dollars in Millions)*

	FY 2009 Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request
Biological Sciences	$56.60	-	$56.60	$56.60
Computer and Information Science and Engineering	11.65	-	11.00	11.00
Engineering	140.02	35.00	148.00	156.37
Geosciences	0.85	-	6.33	0.85
Mathematical and Physical Sciences	194.27	72.81	190.59	172.26
Office of International Science and Engineering	1.73	-	-	-
Social, Behavioral and Economic Sciences	0	-	1.67	1.67
Subtotal, Research and Related Activities	$405.12	$107.81	$414.19	$398.75
Education and Human Resources	3.5	-	3.50	2.50
Total, National Nanotechnology Initiative	$408.62	$107.81	$417.69	$401.25

* Totals may not add due to rounding

NSF supports nanoscale science and engineering in all disciplines throughout all research and education directorates as a mean of advancing discovery and innovation and integrating various fields of research. NNI enables increased interdisciplinarity from atomic and molecular levels for about 5,000 active awards representing more than 10% of all NSF award portfolio. About 10,000 students and teachers are educated and trained in nanoscale science and engineering this year. NSF contributes to the goals and eight program component areas (PCAs) outlined in the NNI Strategic Plan (www.nano.gov). A main increase in 2011 is for nanomanufacturing with a budget of $32.20. Environmental, health and safety implications of nanotechnology, including development of predictive toxicity of nanomaterials, will be investigated in three dedicated multidisciplinary centers and over other 60 smaller groups with a total annual budget of $33.01 million. The modes of support include single investigator, multidisciplinary team, center, and network awards. Ten networks for research, education, and user facilities would be operating in 2010 (see Table 2). The Major Research Instrumentation Program and other programs would continue to support the creation of smaller academic nanoscale science and engineering facilities. NNI activities at NSF are coordinated by the Nanoscale Science and Engineering (NSE) Group.

Table 2. NNI R&D centers, user facilities, and networks (March 2010).

Name	**Institution(s)**
NSF – ten networks	
National Nanofabrication Infrastructure Network (NNIN) – 15 nodes (user facilities)	Cornell University – main node
Network for Computational Nanotechnology (NCN) – 7 nodes (user facilities)	Purdue University – main node
National Nanomanufacturing Network (NNN)	University of Massachusetts, Amherst – main node
Nanotechnology in Society Network (NCN)	Arizona State University and University of California, San Diego
Nanoscale Center for Learning and Teaching (NCLT)	Northwestern University – main node
Nanoscale Informal Science Education (NISE) Network	Museum of Science, Boston – main node
Nanoscale Science and Engineering Centers (NSEC)	University of Columbia – main node

Materials Science and Engineering Centers (MRSECs)	Distributed centers
Centers for the Environmental Implications of Nanotechnology (CEIN)	University of California, Los Angeles, and Duke University
Center for National Nanotechnology Applications and Career Knowledge (NACK)	Pennsylvania State University
DOE – one network of five user facilities	
Center for Functional Nanomaterials	Brookhaven National Laboratory
Center for Integrated Nanotechnologies	Sandia National Laboratory and Los Alamos National Laboratory
Center for Nanophase Materials Sciences	Oak Ridge National Laboratory
Center for Nanoscale Materials	Argonne National Laboratory
Center for Molecular Foundry	Lawrence Berkeley National Laboratory
NIH – four networks	
NHLBI Program of Excellence in Nanotechnology	Four distributed centers
Nanomedicine Development Centers	Eight distributed centers
Centers of Cancer Nanotechnology Excellence	Eight distributed centers
Nanotechnology Characterization Laboratory (user facilities)	Frederick, Md. campus
NIST – two user facilities	
Center for Nanoscale Science and Technology (CNST)	Gaithersburg, Md. campus
NIST advanced nanofabrication facility (NanoFab)	Gaithersburg, Md. campus

DEPARTMENT OF DEFENSE (DOD)

The FY 2011 request for DOD is $349 million, a decrease from the FY 2009 estimate in the current plan, which includes congressionally directed funds (see Table I-8). Because DOD is a mission-oriented agency, its nanotechnology programs are simultaneously focused on scientific and technical merit and potential relevance to DOD. The principal DOD participants in the NNI are the Directorate for Defense Research and Engineering (DDR&E), the Defense Advanced Research Projects Agency (DARPA), the Air Force, the Army, and the Navy. The Defense Threat Reduction Agency (DTRA), the U.S. Army Medical Research and Material Command, and the Manufacturing Technology (MANTECH) program are evaluating nanotechnology as an investment area. DOD supports nanoscale science and technology in order to meet the national security mission.

DEPARTMENT OF HEALTH AND HUMAN SERVICES (HHS): NATIONAL INSTITUTES OF HEALTH (NIH), NATIONAL INSTITUTE FOR

OCCUPATIONAL SAFETY AND HEALTH (NIOSH), AND FOOD AND DRUG ADMINISTRATION (FDA)

The total HHS request for nanotechnology in FY 2011 is $414 million, which would support activities in NIH ($382 million, an increase of $22 million over FY 2010 estimation), NIOSH ($17 million, and increase of $7 million), and FDA ($15 million, first year of funding).

The FY 2011 **NIH** request would be invested in several roadmap initiatives[5]. NIH's priority for nanotechnology research continues to be creating novel diagnostic and therapeutic approaches and devices, and operating research capabilities to understand fundamental biomedical mechanisms. A consortium of 17 NIH institutes re-released the solicitation, Nanoscience and Nanotechnology for Biology and Medicine, both for regular research grants and feasibility projects. Large centers and related programs at the National Cancer Institute (NCI), National Heart, Lung, and Blood Institute (NHLBI), and Nanomedicine Roadmap Initiative would continue in 2011. There is a continued ramp-up of nanotechnology R&D funding for programs including implementing the Nanomedicine Roadmap Initiative, the NCI's Nanotechnology Platform Partnerships and Nanotechnology Characterization Laboratory, the NHLBI's Programs of Excellence in Nanotechnology, and the Nanotechnology Program Area at the National Institute of Biomedical Imaging and Bioengineering.

The FY 2011 **NIOSH** request would allow intramural and extramural projects targeted to addressing critical research gaps around occupational safety and health of nanotechnology and nanomaterials. NIOSH will operate the Center of Excellence for Nanotechnology Research, with the role of coordinating nanotechnology-related activities across the institute and addressing critical occupational health issues. The agency plans to continue to develop partnerships with stakeholders and other organizations to enable the translation of agency activities into appropriate workplace practices.

The FY 2011 **FDA** request will support responsible development of nanotechnology in several environment, health, and safety priorities: laboratory and product testing capacity; scientific staff development and training; and collaborative and interdisciplinary research to address product characterization and safety. The work is done under the auspices

[5] http://nihroadmap.nih.gov

of the FDA Nanotechnology Task Force and Nanotechnology Interest Group (NTIG),

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The FY 2011 request for EPA is $20 million, a $2 million increase from the FY 2010 estimate. In line with EPA's Nanotechnology White Paper (2007) and its strategic planning process, this program includes intramural research within EPA's Office of Research and Development, as well as the extramural program that has been in place for several years. EPA has launched a collaborative process on Nanoscale Materials Stewardship for voluntary reporting of nanomaterials production under the provisions of the Toxic Substances Control Act (TSCA). EPA would continue to focus the majority of its research in 2011 on health and environmental implications of nanomaterials. EPA would increase its efforts in the area of risk assessment and risk management needs for nanomaterials. Finally, EPA would research nanoscale technologies as potential solutions to environmental problems.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

The FY 2011 NASA request for nanotechnology programs is $16 million. The NASA Office of Advanced Technology Program integrates nanotechnology development in three areas: materials and structures; nanoelectronics and computing; and sensors and spacecraft components. A major focus is to advance and exploit the zone of convergence between nanotechnology, biotechnology, and information technology. In addition to basic nanoscience and nanotechnology research, NASA plans to invest in various application areas.

DEPARTMENT OF HOMELAND SECURITY (DHS)

The FY 2011 request for DHS nanotechnology programs is approximately $12 million. The funding increase would enable planned program scope changes associated with transitioning of technologies from proof of concept to prototype development. The DHS Directorate for Science and Technology (S&T) supports nanotechnology research that will enable critical enhancements to homeland security applications in advanced threat detection systems and materials and systems for mitigation and blast protection.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

The NIST FY 2010 budget request for nanotechnology is $108 million. The Center for Nanoscale Science and Technology (CNST, Gaithersburg campus) will focus on collaborative nanotechnology research on cost-effective manufacturing of products made with components the size of atoms and molecules. Additional foci at NIST include the development of standard reference materials for nanotechnology and research related to nanomanufacturing, as well as nanoelectronics. NIST has a large range of collaborations with industry.

? NIST funding for EHS aspects of nanotechnology would increase from $3.2 million in FY 2009 to $6.2 million in FY 2010 to advance the development of an accurate characterization framework urgently needed by all federal agencies. NIST has also established a series of collaborative research programs focused on the new area of quantum nanotechnology.

DEPARTMENT OF AGRICULTURE (USDA): COOPERATIVE STATE RESEARCH, EDUCATION AND EXTENSION SERVICES (CSREES) AND FOREST SERVICE (FS)

The FY 2011 request for USDA is approximately $9 million for NIFA and $5 million for Forest Service. USDA conducts its nanotechnology research both in-house, at Agriculture Research Service (ARS) National Laboratories, and extramurally, through the partnership between the CSREES, the land grant universities (LGUs), and SBIR. The CSREES also provides leadership and financial support for education and outreach in all the states and territories of the United States through the LGUs.

CSREES's Agriculture and Food Research Initiative (AFRI) priorities include detection and intervention technologies for enhancing food safety and agricultural biosecurity; effective and safe delivery of bioactives in functional foods for improving human health and wellness; and product traceability, identity preservation, and tracking to embrace the continuous advancement of information technology for better decision-making. The FS plans to focus on applications of nanotechnology to enhance utilization of forest resources and research on low-cost forest product feedstocks for nanomanufacturing. The FS would support research to determine the basic nanoscale cell wall architecture of wood and bark, wood–binder interaction, and utilization of nano-carbon materials recovered from gasification of woody biomass, as well

as characterization of nanoscale structures of chemically and physically altered wood fiber cell wall surfaces.

Consumer Product Safety Commission (CPSC)

CCPSC joins the NNI budget crosscut for the first time in 2011 with a request of $2.2 million for environment, health, and safety area. Program plans include: developing protocols to assess the potential release of airborne nanoparticles from various consumer products and to determine their contributions to human exposure; determining whether nanomaterials can be used for performance improvement in sports safety equipment such as helmets and kneepads without creating other health hazards; expanding consumer product testing using scientifically credible protocols to evaluate the exposure potential from nanosilver in consumer products, with special emphasis on exposures to young children; and working across agencies to assure that shared common public health concerns are met in research studies to determine potential impacts on the public health of nanomaterial use in consumer products.

DEPARTMENT OF TRANSPORTATION (DOT)

The DOT Federal Highway Administration (FHWA) budget request for approximately $2 million in FY 2011 would support research aimed at improving fundamental understanding of the structure and properties of highway construction materials at the nanoscale.

DEPARTMENT OF JUSTICE (DOJ)

The DOJ National Institute of Justice (NIJ) has two programs that involve nanotechnology. The first program, DNA Research and Development, would continue basic research as well as the demonstration of chip-based or micro-device technologies to analyze DNA in forensic applications. The second program, Chemical and Biological Defense, is developing wearable, low-cost devices using nanotechnology to provide warning of exposure to unanticipated chemical and biological hazards in sufficient time for its wearer to take effective protective measures.

Appendix A. NNI members (25 federal departments and agencies)

Federal Agencies Participating in the NNI (March 2010)
Federal agencies (15) with budgets dedicated to nanotechnology research and development
Consumer Product Safety Commission (CPSC) Department of Defense (DOD) Department of Energy (DOE) Department of Homeland Security (DHS) Department of Justice (DOJ) Department of Transportation (DOT, including the Federal Highway Administration, FHWA) Environmental Protection Agency (EPA) Food and Drug Administration (FDA, DHHS) Forest Service (FS, Department of Agriculture) National Aeronautics and Space Administration (NASA) National Institute for Occupational Safety and Health (NIOSH, DHHS/Centers for Disease Control and Prevention) National Institute of Food and Agriculture (NIFA, Department of Agriculture)[6] National Institutes of Health (NIH, DHHS) National Institute of Standards and Technology (NIST, DOC) National Science Foundation (NSF)
Other participating agencies (10)
Bureau of Industry and Security (BIS, Department of Commerce) Department of Education (DOEd) Department of Labor (DOL) Department of State (DOS) Department of the Treasury (DOTreas) Director of National Intelligence (DNI) International Trade Commission (ITC) Nuclear Regulatory Commission (NRC) U.S. Geological Survey (USGS, Department of the Interior) U.S. Patent and Trademark Office (USPTO, Department of Commerce)

[6] Section 7511 of the Food, Conservation, and Energy Act of 2008 (FCEA) established within the Department of Agriculture the National Institute of Food and Agriculture (NIFA) and transferred all authorities of the Cooperative State Research, Education, and Extension Service (CSREES) to NIFA not later than October 1, 2009.