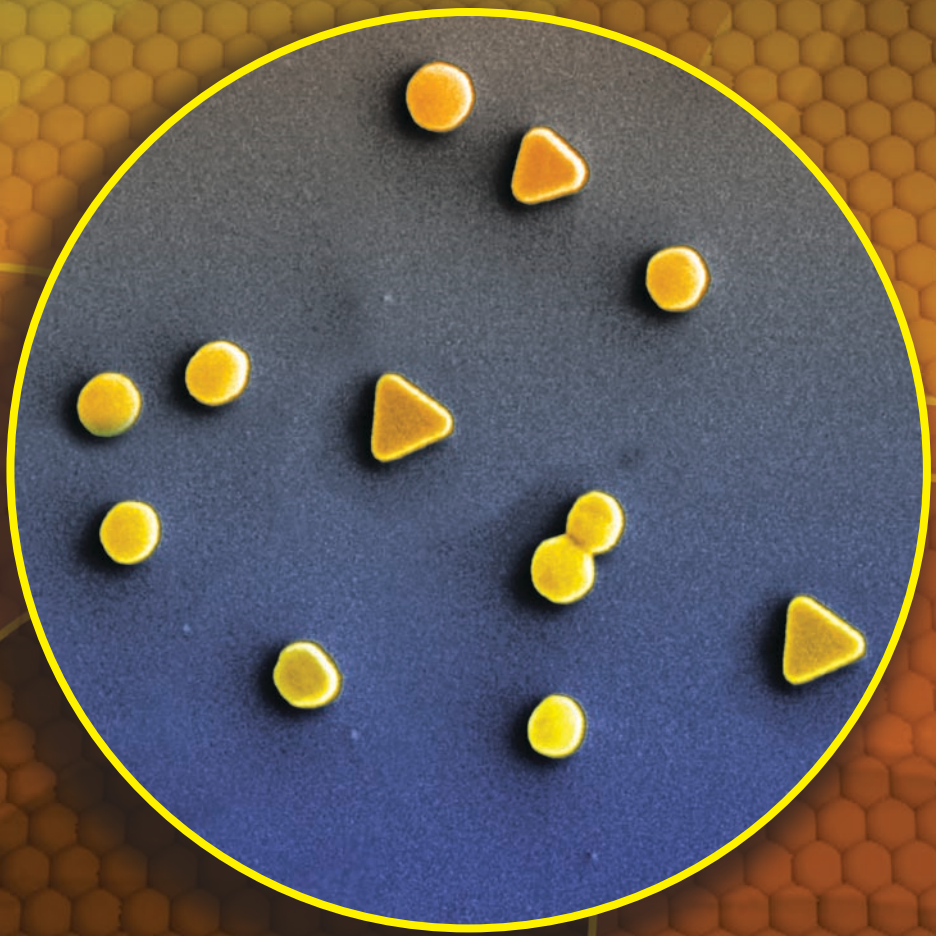
THE NATIONAL NANOTECHNOLOGY INITIATIVE

Research and Development Leading to a Revolution in Technology and Industry

Supplement to the President's FY 2009 Budget



EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

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About this document

This document is a supplement to the President's 2009 Budget Request submitted to Congress on February 4, 2008. It gives a description of the activities underway in 2008 and planned for 2009 by the Federal Government agencies participating in the National Nanotechnology Initiative (NNI), primarily from a programmatic and budgetary perspective. It is based on the NNI Strategic Plan released in December 2007 and reports estimated investments for 2008 and requested investments for 2009 by program component area (PCA), as called for under the provisions of the 21st Century Nanotechnology Research and Development Act (Public Law 108-153). Additional information regarding the NNI is available on the NNI website at http://www.nano.gov/.

About the cover

The central image shows 60 nanometer diameter gold nanoparticles imaged by the new helium ion microscope at the National Institute of Standards and Technology (NIST). These particles are examples of the series of gold reference materials developed by NIST in cooperation with the Nanotechnology Characterization Laboratory at the National Cancer Institute, and thus are also examples of the interagency collaboration that has been the hallmark of the National Nanotechnology Initiative. Background image: idealized representation of a scanning tunneling microscope image of C_{60} molecules on a flat silver surface. Additional technical and ordering information for the new NIST nanoparticle reference materials is available at https://srmors.nist.gov for Reference Materials 8011, 8012, and 8013.

Cover and book design

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The National Nanotechnology Initiative

Research and Development Leading to a Revolution in Technology and Industry

Supplement to the President's 2009 Budget

September 2008

Subcommittee on Nanoscale Science, Engineering, and Technology
Committee on Technology
National Science and Technology Council

Report prepared by

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EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
Washington, D.C. 20502

September 30, 2008

MEMBERS OF CONGRESS:

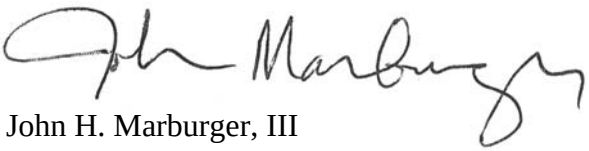
I am pleased to forward with this letter the annual report on the multi-agency National Nanotechnology Initiative (NNI). This Supplement to the President's Budget for Fiscal Year 2009 describes the programs and activities taking place across all 25 of the agencies that are participating today in the NNI. Nanotechnology research and development (R&D) is inherently multidisciplinary and the rate of progress depends on the strong interagency coordination that is taking place, as described in this report, to leverage expertise throughout the Federal Government.

The NNI is now in its eighth year, and the proposed budget for Fiscal Year (FY) 2009 has grown to more than triple the amount spent at the outset in FY 2001, bringing the cumulative investment since the inception of the NNI to just under $10 billion. This sustained investment is advancing our understanding of the unique phenomena and processes that occur at the nanometer scale and is expediting the responsible use of this knowledge to address national and global needs in the areas such as energy, security, and public health. Looking forward, the NNI released a revised Strategic Plan in December 2007 that highlights ten high-impact application opportunities and critical research needs, which illustrate examples of the potential benefits that nanotechnology offers.

Along with its investment in the development and application of nanotechnology, the NNI supports a coordinated program, with participation by both research and regulatory agencies, to understand potential health and environmental effects of nanotechnology. One major achievement with respect to that issue was the release in February of this year of the first comprehensive NNI *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research*. The NNI continues to expand its activities to assess and address societal and ethical concerns associated with this emerging area of technology.

In the coming years and decades, advances in nanotechnology will lead to new products, tools, processes, and ways of doing business. Whereas the economic impact is difficult to estimate, the widespread potential argues for continued public and private investments. As described in this report, the NNI is taking steps to leverage resources across all agencies to ensure that the Federal program leads to the expeditious and responsible development of nanotechnology for the Nation's benefit and in support of our continued global leadership.

Sincerely,



John H. Marburger, III
Director

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1. Introduction and Overview

Overview of National Nanotechnology Initiative

The National Nanotechnology Initiative (NNI) is a U.S. Government interagency, cross-cut program initiated in 2001[1] that coordinates Federal nanoscale research and development activities and related efforts among various participating agencies. The NNI is aimed at accelerating the discovery, development, and deployment of nanometer-scale science, engineering, and technology. Currently the NNI involves the nanotechnology-related activities of 25 Federal agencies, 13 of which have budgets for nanotechnology research and development (R&D) for 2009 (see Table 1).

The NNI released an updated strategic plan in December 2007.[2] This plan sets out a vision for the NNI: *a future in which the ability to understand and control matter at the nanoscale leads to a revolution in technology and industry that benefits society*. The NNI Strategic Plan also specifies four goals aimed at achieving that overall vision: (1) advance a world-class nanotechnology research and development program; (2) foster the transfer of new technologies into products for commercial and public benefit; (3) develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; and (4) support responsible development of nanotechnology.

Toward these goals, the NNI agencies have:

- Created a world-class scientific and engineering R&D enterprise, as evidenced by U.S. leadership in nanotechnology-related publications in three leading international scientific journals, and in its share of citations in leading nanoscience and nanotechnology journals[3] (goal 1)
- Leveraged its investments broadly, catalyzing increased investments in the private sector and around the world[4] (goals 1, 2, and 4)

What is Nanotechnology?

Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale.

A nanometer is one-billionth of a meter. A sheet of paper is about 100,000 nanometers thick; a single gold atom is about a third of a nanometer in diameter. Dimensions between approximately 1 and 100 nanometers are known as the nanoscale. Unusual physical, chemical, and biological properties can emerge in materials at the nanoscale. These properties may differ in important ways from the properties of bulk materials and single atoms or molecules.

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[1] **General note:** In conformance with Office of Management and Budget style, references to years in this report are to fiscal years unless otherwise noted.

[2] http://www.nano.gov/NNI_Strategic_Plan_2007.pdf.

[3] See the April 2008 report of the National Nanotechnology Advisory Panel (PCAST/NNAP 2008) for data supporting this statement: http://ostp.gov/galleries/PCAST/PCAST_NNAP_NNI_Assessment_2008.pdf, pp. 11–14.

[4] PCAST/NNAP 2008, p. 9.

Table 1 List of Federal Agencies Participating in the NNI During 2008
Federal agencies with budgets dedicated to nanotechnology research and development
Cooperative State Research, Education, and Extension Service (CSREES, Department of Agriculture) Department of Defense (DOD) Department of Energy (DOE) Department of Homeland Security (DHS) Department of Justice (DOJ) Department of Transportation (DOT) Environmental Protection Agency (EPA) Forest Service (FS, Department of Agriculture) National Aeronautics and Space Administration (NASA) National Institute of Standards and Technology (NIST, Department of Commerce) National Institute for Occupational Safety and Health (NIOSH, Department of Health and Human Services/Centers for Disease Control and Prevention) National Institutes of Health (NIH, Department of Health and Human Services) National Science Foundation (NSF)
Other participating agencies
Bureau of Industry and Security (BIS, Department of Commerce) Consumer Product Safety Commission (CPSC) Department of Education (DOEd) Department of Labor (DOL) Department of State (DOS) Department of the Treasury (DOTreas) Food and Drug Administration (FDA, Department of Health and Human Services) International Trade Commission (ITC) Intelligence Advanced Research Projects Activity (IARPA) Nuclear Regulatory Commission (NRC) U.S. Geological Survey (USGS, Department of the Interior) U.S. Patent and Trademark Office (USPTO, Department of Commerce)

- Created a culture of interdisciplinary research within the U.S. R&D community through strong incentives for interdisciplinary research at our major research institutions and through NNI-funded interdisciplinary networks, centers of excellence, and user facilities, leading to the development of a new generation of talented multidisciplinary researchers (goals 1 and 3)
- Played a central role in overcoming barriers to nanotechnology innovation and commercialization, through basic and application-targeted research support, critical infrastructure development, and education and training[5] (goal 2, with relevance to all other goals)
- Put in place an updated NNI Strategic Plan reflecting a coordinated overall approach for achieving the NNI goals

[5] Ibid., p. 17.

- Funded over $290 million in nanotechnology-related Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) projects between 2004 and 2007 to aid in the commercialization of nanotechnology (goal 2)
- Identified, in the newly updated NNI Strategic Plan, ten examples of high-impact application opportunities and research needs where NNI-funded research can have a significant impact on critical national needs and major industrial sectors (goal 2)
- Created a world-class R&D infrastructure, including an extensive network of over 60 research centers, user facilities, and other infrastructure for nanotechnology research, enabling broader participation in leading-edge research and multidisciplinary collaborations, and accelerating technology innovation towards functional applications[6] (goal 3, with relevance to all other goals)
- Trained thousands of undergraduate and graduate students in nanoscale science and technology, providing the pipeline for nanotechnology workers and researchers that industry needs in order to commercialize the results of basic research in nanoscale science and technology (goal 3)[7]
- Developed an ongoing process for planning and prioritizing nanotechnology-related environmental, health, and safety (EHS) research, leading to the publication in February 2008 of the first comprehensive NNI strategy for EHS research,[8] thus promoting commercialization of nanotechnology-based applications that are now emerging, while protecting public health, safety, and the environment (goal 4, with relevance to all other goals)
- Funded over $250 million in EHS research since the NNI began reporting EHS research separately in 2005, including the 2009 request outlined in this document (goal 4)
- Funded over $180 million in education and societal dimensions R&D since 2005, including public outreach and research on ethical, legal, and other societal implications (ELSI) of nanotechnology (goal 4)

The December 2007 NNI Strategic Plan lays out eight categories of investment, or program component areas (PCAs), within the NNI, each aimed at helping to achieve one or more of the above goals:

1. Fundamental nanoscale phenomena and processes
2. Nanomaterials
3. Nanoscale devices and systems
4. Instrumentation research, metrology, and standards for nanotechnology
5. Nanomanufacturing
6. Major research facilities and instrumentation acquisition
7. Environment, health, and safety
8. Education and societal dimensions

Federal agencies are investing in R&D within the above categories in support of national goals and agency missions. NNI funding as reported in this supplement represents the collective funding allocated by the participating agencies. Each agency separately determines its budgets for nanotechnology R&D, in coordination with the Office of Management and Budget, the Office of Science and Technology Policy,

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[6] Ibid., p. 9. For more details on the NNI infrastructure, see the NNI Supplement to the President's 2008 Budget, http://www.nano.gov/NNI_08Budget.pdf, pp. 20–22 and pp. 29–33.

[7] See Table 6 on page 11 that provides a list of agencies funding SBIR and STTR grants.

[8] *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research*, http://www.nano.gov/NNI_EHS_Research_Strategy.pdf.

and Congress. The NNI is therefore an interagency budget crosscut in which participating agencies are working closely with each other to create an integrated program through communication, coordination, and joint programs, as appropriate. This also creates a synergy between the individual agency programs that results in the NNI being greater than the sum of its parts.

Purpose of this Report

This document provides supplemental information to the President's 2009 Budget and serves as the Annual Report on the NNI called for in the 21st Century Nanotechnology Research and Development Act (P.L. 108-153). In particular, the report summarizes NNI programmatic activities for 2007 and 2008, as well as those planned for in 2009. NNI budgets for 2007–2009 are presented by agency and PCA. Information on the use of the SBIR and STTR program funds to support nanotechnology research and commercialization activities, also called for in P.L. 108-153, is included at the end of Section 2 of this report. Section 3 discusses activities that have been undertaken and progress that has been made toward achieving the goals set out in the NNI Strategic Plan, and includes an analysis of external reviews of the NNI and how their recommendations are being addressed.

2. NNI INVESTMENTS

Budget Summary

The 2009 Budget provides $1.5 billion for the National Nanotechnology Initiative (NNI), reflecting steady growth in the NNI investment. This sustained major investment in nanotechnology research and development (R&D) across the Federal Government over the past nine fiscal years of the NNI reflects the broad support of the Administration and of Congress for this program. This support is based on nanotechnology's potential to vastly improve our fundamental understanding and control of matter, ultimately leading to a revolution in technology and industry for the benefit of society. The NNI remains focused on fulfilling the Federal role of supporting basic research, infrastructure development, and technology transfer, in the expectation that the resulting advances and capabilities will make important contributions to national priorities, with applications across a wide range of industries including healthcare, electronics, aeronautics, agriculture and food, and energy. The NNI also is committed to implementing its comprehensive strategy for environmental, health, and safety (EHS) research. Increasing investments by NNI participating agencies in nanotechnology-related research since 2001 reflect a recognition of the potential for this research to support agency missions and responsibilities. The cumulative NNI investment since 2001, including the 2009 request, now totals almost $10 billion. Cumulative investments in EHS research since 2005 now total over $250 million. Cumulative investments in education and in research on ethical, legal, and other societal dimensions of nanotechnology since 2005 total over $180 million.

The 2009 NNI budget supports nanoscale science and engineering R&D at 13 agencies. Agencies with the largest investments are:

- DOD (science and engineering research advancing defense and dual-use capabilities)
- NSF (fundamental research across all disciplines of science and engineering)
- DOE (research providing a basis for new and improved energy technologies)
- NIH (nanotechnology-based biomedical research at the intersection of life sciences and the physical sciences)
- NIST (fundamental research and development of measurement and fabrication tools, analytical methodologies, and metrology for nanotechnology)

Other agencies investing in mission-related research are NASA, NIOSH, EPA, USDA (including both CSREES and FS), DHS, DOJ, and DOT (including the Federal Highway Administration, FHWA).

Table 2 shows NNI investments in 2007–2009 for Federal agencies with budgets and investments for nanotechnology R&D. Tables 3–5 list the investments by agency and by program component area (PCA). The program component areas shown in these tables are those outlined in the new NNI Strategic Plan released in December 2007, with nanotechnology-related EHS research now reported in a separate PCA. Table 6 (p. 12) shows nanotechnology-related SBIR and STTR investments for 2004–2007.

Key points about the 2008 and 2009 NNI investments

- The 2009 NNI budget provides increased support for research on fundamental nanoscale phenomena and processes from $481 million in 2007 to $551 million in 2009, arising mostly from increased investments at DOE's Office of Science for basic research on energy applications of nanoscience.
- Increases in nanotechnology R&D funding for DOE, NIST, and NSF reflect the President's continuing commitment to significantly increase funding for physical sciences and engineering research as part of the American Competitiveness Initiative.

Table 2 NNI Budget, 2007–2009 (dollars in millions)			
	2007 Actual	**2008 Estimate**	**2009 Proposed**
DOD*	450	487	431
NSF	389	389	397
DOE**	236	251	311
DHHS (NIH)	215	226	226
DOC (NIST)	88	89	110
NASA	20	18	19
EPA	8	10	15
DHHS (NIOSH)	7	6	6
USDA (FS)	3	5	5
USDA (CSREES)	4	6	3
DOJ	2	2	2
DHS	2	1	1
DOT (FHWA)	1	1	1
TOTAL	**1,425**	**1,491**	**1,527**

* The 2008 DOD estimate exceeds the 2008 request by $112 million but includes Congressionally directed funding that is outside the NNI plan (as is also true for the 2007 actual funding).

** Funding levels for DOE include the Offices of Science, Fossil Energy, and Energy Efficiency and Renewable Energy.

- The proposed budget also reflects substantial ongoing growth in funding for instrumentation research, metrology, and standards (from $53 million in 2007 to $82 million in 2009) and in nanomanufacturing research (from $48 million in 2007 to $62 million in 2009). Through a series of workshops, NNI agencies are gathering input and feedback from industry and the research community on these growing investments.
- The proposed budgets for nanotechnology R&D of EPA and USDA (FS) in 2009 are almost double those in 2007.
- EHS R&D funding in 2009 ($76 million) is over double the level of actual funding in 2005 ($35 million)—the first year these data were collected. The steady growth in EHS R&D spending supports the NNI strategy of expanding the capacity to do high-quality research in this field. For tables in this document, *EHS R&D is defined as research whose primary purpose is to understand and address potential risks to health and to the environment posed by nanotechnology.* Therefore the proposed $76 million for 2009 does not include substantial research reported under other PCAs, e.g., on instrumentation and metrology and on fundamental interactions between biosystems and engineered nanoscale materials, both of which are important in the performance and interpretation of toxicological research. An indication of the total level of funding in support of nanotechnology-related EHS research, including these broader categories, may be deduced from the detailed 2006 data collected and analyzed specifically for this purpose and published in the February 2008 NNI report, *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research*.[9] If these vital related areas were included, current funding figures for EHS research would be as much as 60% higher.

[9] http://www.nano.gov/NNI_EHS_Research_Strategy.pdf.

Table 3
Actual 2007 Agency Investments by Program Component Area
(dollars in millions)

	Fundamental Phenomena & Processes	Nanomaterials	Nanoscale Devices & Systems	Instrument Research, Metrology, & Standards	Nano-manufacturing	Major Research Facilities & Instr. Acquisition	Environment, Health, and Safety	Education & Societal Dimensions	NNI Total
DOD	210.1	86.0	120.0	4.3	7.5	22.3			450.2
NSF	145.2	58.4	52.4	14.9	26.6	30.0	26.9	34.4	388.8
DOE	52.6	68.5	9.7	11.3	0.5	92.9		0.5	236.0
DHHS (NIH)	45.7	25.4	125.7	5.9	0.8		7.7	4.2	215.4
DOC (NIST)	24.2	7.5	22.9	14.2	12.4	5.5	0.9		87.6
NASA	0.8	9.9	9.1						19.8
EPA	0.2	0.2	0.1				7.1		7.6
DHHS (NIOSH)						1.7	5.6		7.3
USDA (FS)	0.4	1.3	0.7	0.3	0.2				2.9
USDA (CSREES)	0.5	1.0	2.1		0.1		0.1	0.1	3.9
DOJ		0.1		1.6					1.7
DHS			2.0						2.0
DOT (FHWA)	0.9								0.9
TOTAL	**480.6**	**258.3**	**344.7**	**52.5**	**48.1**	**152.4**	**48.3**	**39.2**	**1,424.1**

Table 4
Estimated 2008 Agency Investments by Program Component Area
(dollars in millions)

	Fundamental Phenomena & Processes	Nanomaterials	Nanoscale Devices & Systems	Instrument Research, Metrology, & Standards	Nano-manufacturing	Major Research Facilities & Instr. Acquisition	Environment, Health, and Safety	Education & Societal Dimensions	NNI Total
DOD	258.7	68.9	119.8	8.0	5.4	24.6	2.0		487.4
NSF	138.8	62.1	50.3	16.0	26.9	31.6	29.2	33.8	388.7
DOE	51.4	77.5	13.0	12.0	2.0	92.0	3.0	0.5	251.4
DHHS (NIH)	55.6	25.4	125.8	5.9	0.8		7.7	4.6	225.8
DOC (NIST)	22.5	7.4	21.7	16.1	14.4	5.8	0.8		88.7
NASA	1.5	9.7	6.2			0.4	0.2		18.0
EPA	0.2	0.2	0.2				9.6		10.2
DHHS (NIOSH)							6.0		6.0
USDA (FS)	1.3	1.9	1.2	0.4	0.2				5.0
USDA (CSREES)	0.7	1.6	3.1		0.5		0.1	0.1	6.1
DOJ				2.0					2.0
DHS			1.0						1.0
DOT (FHWA)	0.9								0.9
TOTAL	**531.6**	**254.7**	**342.3**	**60.4**	**50.2**	**154.4**	**58.6**	**39.0**	**1,491.2**

Table 5
Planned 2009 Agency Investments by Program Component Area
(dollars in millions)

	Fundamental Phenomena & Processes	Nanomaterials	Nanoscale Devices & Systems	Instrument Research, Metrology, & Standards	Nano-manufacturing	Major Research Facilities & Instr. Acquisition	Environment, Health, and Safety	Education & Societal Dimensions	NNI Total
DOD	227.8	55.2	107.7	3.6	12.8	22.1	1.8		431.0
NSF	141.7	62.5	51.6	16.0	26.9	32.1	30.6	35.5	396.9
DOE	96.9	63.5	8.1	32.0	6.0	101.2	3.0	0.5	311.2
DHHS (NIH)	55.5	25.4	125.8	5.9	0.8		7.7	4.6	225.7
DOC (NIST)	24.5	8.5	22.7	20.9	15.3	5.7	12.8		110.4
NASA	1.2	9.8	7.7			0.2	0.1		19.0
EPA	0.2	0.2	0.2				14.3		14.9
DHHS (NIOSH)							6.0		6.0
USDA (FS)	1.7	1.3	0.7	1.1	0.2				5.0
USDA (CSREES)	0.4	0.8	1.5		0.1		0.1	0.1	3.0
DOJ				2.0					2.0
DHS			1.0						1.0
DOT (FHWA)	0.9								0.9
TOTAL	**550.8**	**227.2**	**327.0**	**81.5**	**62.1**	**161.3**	**76.4**	**40.7**	**1,527.0**

Changes in Balance of Investments by Program Component Area (PCA)[10]

P.L. 108-153 calls for this report to address changes in the balance of investments by NNI member agencies among the PCAs. These are summarized below for those agencies that are reporting significant changes for 2008 and 2009.

DOD: The differences in the 2007–2009 budget numbers and in the balance of investments by PCA are consistent with regular program turnover and the required categorization of data associated with extracting NNI-related activities from the DOD investment portfolio (i.e., determining with which PCA a multifaceted project is most aligned).

NSF: The increase of $8.1 million in NSF's 2009 request will provide additional funding primarily in the following PCAs: fundamental phenomena and processes (increased by $2.5 million), nanoscale devices and systems (increased by $1.3 million), EHS (increased by $1.5 million), and education and societal dimensions (increased by $1.5 million).

DOE: The largest component of DOE nanotechnology funding is within the Office of Science.[11] Those investments increase substantially across most PCAs, with the biggest change in the PCA on Fundamental Nanoscale Phenomena and Processes. Additional investments in the 2009 request correspond to a variety of initiatives in basic research related to various application areas (including solar energy, hydrogen fuels, nuclear systems, and energy storage) that will be implemented through multi-investigator Energy Frontier

[10] Changes are as compared to NNI investments described in the *NNI Supplement to the President's 2008 Budget*.
[11] For more information see http://nano.energy.gov.

Research Centers[12] as well as single-investigator and small group grants. The distribution of these new investments across PCAs has been estimated for 2009, but the eventual distribution will depend on the mix of activities that are proposed and selected for support. In the Office of Energy Efficiency and Renewable Energy (EERE), nanomanufacturing efforts will be enhanced as the office begins research and development to address barriers identified in the Nanomanufacturing for Energy Efficiency Workshop (June 2007)[13] to enable broad applications in energy-intensive industrial processes and development of next-generation manufacturing processes.

NIST: The President's 2009 budget includes a $19 million increase in the NIST budget for research in nanotechnology compared to 2008. Seven million of the increase is distributed across all PCAs without substantially changing the balance of investments by PCA. The remaining $12 million increase in the NIST budget provides a 15-fold increase in funding for EHS aspects of nanotechnology to develop an accurate characterization framework needed by all Federal agencies for timely progress on this topic. NIST will launch a coordinated nanotechnology EHS initiative in 2009, leveraging nanotechnology expertise and resources across its laboratories and facilities to develop analytical methods for quantifying the type and amount of nanomaterials in biological materials, the environment, and the workplace. NIST will develop accurate and validated protocols and reference materials to define the uses and limitations of major analytical methods. Measurement approaches to improve understanding of EHS properties of nanomaterials will be developed, including techniques for standardizing assessment of nanoparticle size and size distribution, shape, structure, and surface area, and for characterizing nanoparticle chemical composition, purity, and heterogeneity.

NIOSH: NIOSH will continue its investments in nanotechnology R&D related to worker health and safety, in close coordination with other agencies (on toxicology research with those participating in the National Toxicology Program and on reference nanomaterials with NIST). This investment will support intramural and extramural projects that address critical research gaps related to occupational safety and health of nanotechnology and nanomaterials.

USDA/CSREES: The major differences in the balance of funding among PCAs between the 2009 request and prior years are mainly due to Congressionally directed funding. The 2009 budget request does not include funding for continuation of Congressionally directed funding, as is standard USDA practice.

Utilization of SBIR and STTR Programs to Advance Nanotechnology

As called for by the 21st Century Nanotechnology Research and Development Act, this report includes information on use of the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs in support of nanotechnology development. Five NNI agencies—DOD, NSF, NIH, DOE, and NASA—have both SBIR and STTR programs. In addition to these agencies, EPA, NIOSH, NIST, and USDA have SBIR programs. Table 6 shows 2004 through 2007 (the latest year for which data is available) agency funding for SBIR and STTR awards for nanotechnology R&D. These figures reflect revised estimates for some agencies and some years compared to figures published in previous NNI budget supplement reports, as described in the footnotes under the table.

Some NNI agencies (e.g., EPA and NIH) have nanotechnology-specific topics in their SBIR and STTR solicitations. Some (e.g., NIH and NSF) have had topical or applications-oriented solicitations for which many awardees have proposed nanotechnology-based innovations. NIOSH reported nanotechnology-related SBIR funding for the first time in 2006. All told, with this revised data for 2004–2007, the NNI

[12] http://www.science.doe.gov/bes/EFRC.html.
[13] See the final report from the workshop at http://eenm.govtools.us/.

agencies have funded over $290 million of nanotechnology-related SBIR and STTR awards since 2004. More information about the NNI agencies' use of the SBIR and STTR awards for nanotechnology innovation and commercialization is provided on page 21.

Table 6
2004–2007 Agency SBIR and STTR Awards
(dollars in millions)

	2004			2005			2006			2007		
	SBIR	**STTR**	**Total**	**SBIR**	**STTR**	**Total**	**SBIR**	**STTR**	**Total**	**SBIR**	**STTR**	**Total**
DOD*	10.5	6.9	17.4	7.5	5.5	13	12.6	5.6	18.2	8.4	4.2	12.6
NSF	11.9	0.9	12.8	12.1	5.5	17.6	13.9	1.8	15.7	13.4	3.8	17.2
DOE	6.8	2.8	9.6	7.7	0.4	8.1	18.2	1.6	19.8	17.4	0.8	18.2
DHHS (NIH)	9.3	2.6	11.9	11.1	5.2	16.3	15.1	2.1	17.2	18.4	1.1	19.5
DOC (NIST)	0.5		0.5	0.1		0.1	0.1		0.1	0.3		0.3
NASA**	7.2	0.6	7.8	6		6	12.1	1.5	13.6	11.7	1.5	13.2
EPA	0.6		0.6	1		1	1.2		1.2	0.5		0.5
DHHS (NIOSH)							0.1		0.1	0.1		0.1
USDA***	0.8		0.8	1		1	0.7		0.7	1.1		1.1
TOTAL	47.6	13.8	61.4	46.5	16.6	63.1	74.0	12.6	86.6	71.3	11.4	82.7

* DOD revised its SBIR and STTR funding levels for FY 2004.

** NASA revised its SBIR and STTR funding levels for FY 2006.

*** USDA revised its SBIR funding levels across all years.

3. Progress Towards Achieving NNI Goals and Priorities

Introduction: Overview of NNI Structure and Management

The National Nanotechnology Initiative is managed within the framework of the National Science and Technology Council (NSTC), the Cabinet-level council by which the President coordinates science and technology policy across the Federal Government. The Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the NSTC coordinates planning, budgeting, program implementation, and review of the initiative. The NSET Subcommittee is composed of representatives from agencies participating in the NNI. A listing of official NSET Subcommittee members is provided at the front of this report. Contact information for NSET Subcommittee participants is provided in Appendix B. The National Nanotechnology Coordination Office (NNCO) acts as the primary point of contact for information on the NNI; provides technical and administrative support to the NSET Subcommittee; supports the subcommittee in the preparation of multiagency planning, budget, and assessment documents, including this report; and develops, updates, and maintains the NNI website, http://www.nano.gov.

The NSET Subcommittee has established several working groups. These include the Global Issues in Nanotechnology (GIN) Working Group; the Nanotechnology Environmental and Health Implications (NEHI) Working Group; the Nanomanufacturing, Industry Liaison, and Innovation (NILI) Working Group; and the Nanotechnology Public Engagement and Communication (NPEC) Working Group.

As called for in the 21st Century Nanotechnology Research and Development Act, the 2007 NNI Strategic Plan states that the annual interagency analysis of progress under the NNI will be provided in the annual NNI Supplement to the President's Budget. As indicated in the plan, the NNI's activities for 2007 and 2008 and plans for 2009 are reported here in terms of how they promote progress toward the four NNI goals. Goal-related activities are in turn reported in terms of three categories of activities: (1) coordinated interagency activities, (2) individual agency activities, and (3) engagement with groups and activities external to the NNI, including international activities. A brief report of progress toward the NNI goals in terms of these three categories follows. *The activities described below are only selected highlights of current and planned work of the NNI member agencies and are not an all-inclusive description of ongoing NNI activities.*

Activities Relating to the Four NNI Goals

Goal 1: Advance a world-class nanotechnology research and development program

Towards this goal, the NNI has funded thousands of individual R&D projects since its inception, contributing to U.S. world leadership in nanotechnology. As indicated in the recently released President's Council of Advisors on Science and Technology/National Nanotechnology Advisory Panel (PCAST/NNAP) review of the NNI,[14] identifying meaningful metrics for evaluating U.S. global leadership in nanotechnology is challenging. But by many of the available measures, the United States continues to lead in both basic and applied research on nanoscale science and technology.

By several different indicators, the United States is indeed advancing a world-class nanotechnology research and development program, in large part under the auspices of the NNI. These indicators include: (1) the high percentage of publication of nanotechnology-related papers by U.S. researchers in three of the world's

[14] PCAST/NNAP 2008, http://ostp.gov/galleries/PCAST/PCAST_NNAP_NNI_Assessment_2008.pdf.

premier scientific journals (*Science*, *Nature*, and *Proceedings of the National Academy of Sciences*),[15] (2) the large number of citations of U.S. papers in peer-reviewed journal publications,[16] and (3) the large number of nanotechnology-enabled patents filed in three or more international patent offices.[17] However, we must not be complacent in evaluating our international competitiveness in nanotechnology. As indicated in the new PCAST/NNAP report, Europe as a whole leads the world in nanotechnology publications in the Science Citation Index (SCI) database, and China and other Asian countries are rapidly gaining on the United States and Europe in nanotechnology-related SCI publications. Therefore we must continue to sustain and increase our strategic investments in this critical area of science and technology.

Coordinated Interagency Activities Contributing to Goal 1

- **DOT/FHWA, NIST:** The Federal Highway Administration continues to support research aimed at improving fundamental understanding of the structure and properties of highway construction materials at the nanoscale. For example, FHWA is working with the Western Research Institute, NIST, and the University of Wyoming to improve understanding of the properties of asphalt at the nanoscale, as well as possible "nano modifications" to improve the performance of asphalt. FHWA is also in the process of evaluating nanotechnology-enabled high-performance concrete formulations, including high-tensile-strength and "ductile" concrete.
- **EPA, NSF, DOE**: These agencies funded projects in 2008 under a joint solicitation, "Nanotechnology Research Grants Investigating Fate, Transport, Transformation, and Exposure of Engineered Nanomaterials." This is the fourth interagency solicitation on nanotechnology led by the National Center for Environmental Research (NCER) of EPA's Office of Research and Development.[18] A new joint solicitation involving EPA, NSF, and other partners is planned for 2009.
- **NIH, NIOSH, EPA:** NIH has taken the lead in an interagency solicitation begun in 2007 with NIOSH and EPA entitled, "Manufactured Nanomaterials: Physico-Chemical Principles of Biocompatibility and Toxicity."[19] Ten awards have been made by the three agencies.
- **NIST, NSF:** In August 2007, scientists from these agencies and from the University of Colorado and Lehigh University led a workshop, "Materials Characterization for Nanoscale Reliability," hosted at the University of Colorado. The participants worked together to catalogue the range of characterization tools needed to most effectively develop, produce, and use nanomaterials, and designed plans for collaborative research to ensure these tools will be available as nanotechnology continues to advance.

Individual Agency Activities Contributing to Goal 1

DOD: DOD maintains a broad and opportunistic view of its 6.1, 6.2, and 6.3 programs that support nanotechnology; there are no significant strategic changes expected in DOD's nanotechnology-related

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[15] Over 70% in 2006; see the 2008 PCAST/NNAP report, p. 12.
[16] U.S. papers averaged 35% over the 2002–2005 period versus the next largest average of about 28% for 25 EU countries; see the PCAST/NNAP report, p. 13.
[17] U.S. assignees were responsible for over 37% of nanotechnology-related patents on the same invention in three or more countries over the period 1985 through 2005 versus the next largest percentage of 24% for Japanese assignees; see the PCAST/NNAP report, p. 14.
[18] Additional information on these and other solicitations can be found at http://www.epa.gov/ncer/nano; see also additional information under Goal 4 later in this report.
[19] http://grants.nih.gov/grants/guide/rfa-files/RFA-ES-06-008.html.

efforts for 2008 or 2009. Additional details are available from DOD's annual report to Congress outlining its nanoscience and nanotechnology R&D programs.[20]

- **DOE:** At DOE's Office of Science, major increases in the 2009 request reflect the nanoscience contributions expected within key research initiative areas in solar energy, hydrogen fuel, electrical energy storage, ultrafast science, emergent behavior, chemical imaging, mid-scale instrumentation, and advanced nuclear energy systems that were planned but could not be supported due to appropriations constraints in the prior two fiscal years. Implementation of these initiatives includes a plan to create a suite of Energy Frontier Research Centers that will encompass larger-scale multi-investigator research, in addition to a significant enhancement in single-investigator and small-group projects. Projections for 2009 are based on estimates of the proportions of funded programs in these areas that will involve or rely upon research at the nanoscale.

- **NIH:** The Trans-NIH Nano Task Force has reissued Funding Opportunity Announcements for regular research and exploratory research grants on nanoscience and nanotechnology, continuing through January 2011.[21] Applications in response to these program announcements are now reviewed by a chartered review panel. The trans-NIH SBIR and STTR nanotechnology programs remain in effect.[22]

  Nanotechnology is more prominent in the NIH research portfolio than in the past, appearing not only in nanotechnology-specific programs but also in a wider array of research and training programs that serve the missions of the various institutes and centers of the NIH. Several examples follow:

  The National Institute of Environmental Health Sciences (NIEHS) plans to support research (under FOA RFA-ES-07-007) as part of the Superfund Basic Research and Training Program (SBRP) to enhance understanding of the basic structural and functional properties of biological populations that are involved in the bioremediation of hazardous substances by integrating or adapting innovative nanotechnology-based tools for sensing, detecting, and elucidating processes at the molecular and nanoscale. NIEHS intends to commit $2 million in 2009 contingent upon the availability of funds.[23]

  The National Cancer Institute (NCI) regards nanotechnology as one of the critically important and innovative tools in attempts to reduce the burden of cancer. NCI established the Alliance for Nanotechnology in Cancer in 2005 to pursue research related to applications of nanotechnology in prevention, diagnosis, and therapy of cancer. The Centers of Cancer Nanotechnology Excellence (CCNE) and nanotechnology grants formed under this program have been very active in pursuing team research, which to date have resulted in almost 600 peer-reviewed publications, over 130 patent disclosures, and contributions to the formation of over 20 companies. The program has been equally active in creating training opportunities to develop a cadre of true multidisciplinary researchers competent in applying the tools and approaches of nanotechnology to critical problems in cancer research.

  NCI intends to commit approximately $2.25 million over 3 years to fund a total of ten new fellowships in Cancer Nanotechnology Research. NCI also plans to foster and support intensive

[20] http://nano.gov/html/res/pdf/DefenseNano2007.pdf.
[21] http://grants.nih.gov/grants/guide/pa-files/PA-08-052.html
http://grants.nih.gov/grants/guide/pa-files/PA-08-053.html.
[22] http://grants.nih.gov/grants/guide/pa-files/PA-06-009.html
http://grants.nih.gov/grants/guide/pa-files/PA-06-008.html.
[23] http://grants.nih.gov/grants/guide/rfa-files/RFA-ES-07-007.html.

collaborations among minority-serving institutions and NCI-designated cancer centers in order to develop stronger national cancer programs aimed at understanding the reasons behind the significant cancer disparities and related impacts on racial and ethnic minority and socio-economically disadvantaged populations. The program encourages research proposals related to cancer in emerging technologies, such as nanotechnology, proteomics, genomics, and imaging. The NCI intends to make initial awards in 2008, and the projects may continue for up to 5 years.[24]

The National Institute of Mental Health (NIMH) and National Institute of Neurological Disorders and Stroke (NINDS) solicited SBIR and STTR projects to develop and commercialize technologies for high-throughput data acquisition and analysis that could aid the research fields of basic behavioral science, neuroscience, or neuroAIDS. This initiative will bring new technologies such as computer vision, molecular biology, robotics, nanotechnology, microarray fabrication, imaging, etc., together with biomedical areas by soliciting applications to develop any of a wide variety of innovative tools for high-throughput analysis of data relevant to brain and/or behavior. These opportunities continue through 2010.[25]

The National Heart, Lung, and Blood Institute (NHLBI) has solicited research project grant and small business grant applications to develop and validate new and innovative engineering approaches to address clinical problems related to energy balance, intake, and expenditure. Novel sensors, devices, imaging, and other technologies, including technologies to detect biochemical markers of energy balance, are expected to be developed and evaluated by collaborating engineers, physical scientists, mathematicians, and scientists from other relevant disciplines with expertise in obesity and nutrition. Emerging technologies such as nanotechnology offer unique opportunities for interfacing with engineering approaches to help address some of the problems in obesity research. These opportunities continue through 2010.[26]

The National Human Genome Research Institute (NHGRI) continues an ambitious program to support the development of technologies to enable complete human genome DNA sequencing for about $1,000.[27] The technology has many other uses, e.g., for rapid and extremely low-cost sequencing of genomes of other animals, plants and microbes, leading to applications in medicine, agriculture, energy, environment, forensics, homeland security, etc. Nanotechnologies provide many of the pathways to achieving this goal. This program, funded by NIH, builds on investments and capabilities provided by several other NNI agencies. NHGRI intends to make awards in this program in 2009.

- **NIST:** NIST is developing measurement science and technology crucial to industry's development of products for a nanotechnology market. NIST is helping to clear technical obstacles, including uncertainties about potential environmental, health, and safety risks, with the aim of opening the way

[24] http://grants.nih.gov/grants/guide/rfa-files/RFA-CA-08-001.html.
[25] http://grants.nih.gov/grants/guide/pa-files/PA-08-001.html
http://grants.nih.gov/grants/guide/pa-files/PA-08-002.html.
[26] http://grants.nih.gov/grants/guide/pa-files/PA-07-354.html
http://grants.nih.gov/grants/guide/pa-files/PA-07-435.html
http://grants.nih.gov/grants/guide/pa-files/PA-07-436.html.
[27] http://grants.nih.gov/grants/guide/rfa-files/RFA-HG-08-008.html
http://grants.nih.gov/grants/guide/rfa-files/RFA-HG-08-009.html
http://grants.nih.gov/grants/guide/rfa-files/RFA-HG-08-010.html
http://grants.nih.gov/grants/guide/rfa-files/RFA-HG-08-011.html.

for a diverse range of prospective payoffs. More than 150 nanotechnology-related research projects are underway in the NIST laboratories, leading to cross-cutting advancements, including the following:

- New measurement tools for ensuring the quality of nanoscale particles, nanotubes, and other nanomaterials that will be the building blocks of new technologies across a multitude of markets, from consumer products to construction and from healthcare to homeland security
- Powerful new imaging and diagnostic tools that exploit the unusual properties of quantum dots and magnetic nanoparticles to "see" and "analyze" cancer and other diseases at the level of individual cells, enabling earlier detection and less-invasive treatment with greater specificity
- Affordable flexible arrays of transistors made from "self-assembling" organic materials that can be manufactured into large plastic displays pliant enough to be folded and stowed inside a cell phone
- Nanowires only a few atoms across, graphene films, and other nanostructured materials that have remarkable properties, like the ability to carry electrons at speeds much higher than possible with conventional materials, and that will be the basis for future generations of computers, sensors, batteries, lasers, and more
- Data storage devices that employ precisely controlled arrays of magnetic nanoparticles to achieve capacities that will dwarf those of today's most advanced hard disk drives
- Improved formulations of cement—perhaps the world's most widely used manufactured material—that perform better and last longer, thanks to a better understanding and control of their nanostructure; improvements include reduced emission of greenhouse gases during production of this workhorse construction material, which currently accounts for 5 to 10 percent of global releases of carbon dioxide

- **NSF:** NSF is supporting research on integrated nanosystems that will enable critical applications such as:
  - Technologies beyond petascale computing and beyond petabyte storage systems
  - Designing in properties by manufacturing materials from the nanoscale
  - Regenerating human tissue and organs from the nanoscale
  - Designing systems of nanometer-sized sensors
  - Selectively filtering harmful particles from water
  - Manufacturing devices that efficiently convert and store renewable energy (e.g., solar cells)

  Other areas of emphasis at NSF include research on nanoscale processes that occur in the cell, at the intracellular level, in neural systems, and at the interfaces between biotic and abiotic materials.

  NSF also expects to increase funding on nanoscale science and engineering research targeted at fundamentally new solutions for nanoelectronics "beyond Moore's Law." The foundation will support programs in three of its research directorates for joint funding with industry of multi-investigator awards to advance nanotechnology research and education. Nanotechnology-related environmental, health, and safety (EHS) research will be included in several core programs.[28]

- **USDA/CSREES:** CSREES's National Research Initiative Nanoscale Science and Engineering for Agriculture and Food Systems program is combining its 2007 and 2008 funding totaling approximately $5 million in a single solicitation in 2008.[29] The program priorities include nanoscale

[28] For more information see http://www.nsf.gov/nano.
[29] http://www.csrees.usda.gov/fo/nanoscalescienceengineeringnri.cfm.

detection and intervention technologies for enhancing food safety and agricultural biosecurity; effective delivery of micronutrients and bioactive ingredients in foods; and product identification, preservation, and tracking.

- **USDA/FS:** In 2008, the Forest Service identified nanotechnology as one of the agency's major research and development growth platforms. In addition, the FS Strategic Framework for Forest Products and Utilization Research and Development[30] identified nanotechnology as one of the emerging areas that needs increased funding in order to address challenges and capitalize on new emerging opportunities in the forest products industry.

  In carrying out high-priority research to advance the agency's strategic growth in nanotechnology, FS scientists are pursuing the following project areas: characterization of the hierarchical structure and mechanical properties of wood cell walls and bark *in situ* at the nanoscale; characterizing and understanding wood-polymer interactions at the nanoscale; nanomanufacturing of wood-based, nanotechnology-enabled composites; production, characterization, and utilization of wood-derived cellulose nanocrystals; development of nanocatalysis for biofuels production; and investigating the use of nanoclays and nanosilver as environmentally preferable wood preservatives.

Engagement with Groups and Activities External to the NNI, Including International Activities, Contributing to Goal 1

- **NIST, University of Maryland-College Park:** Joint efforts by these institutions have resulted in significant progress in several projects on nanomaterials, including growth of aligned carbon nanotubes; discovery that some materials such as silica that are brittle in bulk form are as ductile as gold at the nanoscale; and experiments on the self-assembly of one dimensional chains of "buckyballs" (C60). These projects have long-range application in such areas as flat panel displays, electrodes for chemical sensors and biosensors, and optimization of nanometer-scale devices based on structured surface assemblies of organic molecules.

  NIST, University of Colorado: Joint work has developed a unique way of growing hexagonal gallium nitride (GaN) nanowires featuring low defect density and high luminescence intensity. Because low defect density indicates a capacity for stable vibrations, the nanowires might be used as oscillators in nanoelectromechanical systems for future nanosensors and communications devices. NIST's GaN nanowires are grown on silicon, making them compatible with existing microelectronics processing methods.

  NIST, IBM: Collaboration has enabled deployment of a NIST single-crystal, critical-dimension reference material for z-axis calibration of a critical-dimension atomic force microscope (CD-AFM). NIST developed the measurement procedures for an ASTM documentary standard describing a robust procedure for AFM-based step-height calibrations at the highest levels of resolution. These step-height calibrations made use of the world's first commercially available atom-based dimensional standard and resulted in the publication of the ASTM Standard E2530-06, *Standard Practice for Calibrating the Z-Magnification of an Atomic Force Microscope at Subnanometer Displacement Levels Using Si (111) Monatomic Steps.*

  NIST, University of Warwick, Northwestern University, Hewlett-Packard Laboratories: A collaborative effort among the members of this group has produced a technique for tracing the

[30] http://www.fpl.fs.fed.us/resources-products/fpl/fpurd-plan.pdf.

electronic pathways that a charge carrier follows when transiting a molecular junction. This enables a more detailed understanding of charge transport across metal-molecule-metal junctions, the fundamental building blocks of molecular electronic devices. This understanding is paramount for molecular electronics to transition from a research endeavor into a viable technology.

- **NIST, Federal Aviation Administration (FAA/DOT), University of Maryland:** Researchers are collaborating to determine the mechanism underlying the discovery that rheology plays a fundamental role in improving the fire safety of nanocomposite plastics. This research will enable manufacturers to develop fire-safe products such as foam and fabrics for use by the upholstered furniture and mattress industries.
- **NSF, NIST, Various Industry Sectors (Electronic, Chemical, Modeling and Simulation, Forestry Products):** Partnerships between NSF and these industrial sectors have produced collaborations ranging from informal meetings to invitations to industry researchers to serve on NSF review panels, to joint program announcements. An example is the case of the Nanoelectronics Research Initiative, a joint activity of NSF, NIST, and the Semiconductor Industry Association.[31]
- **NSF, Japan, France, Korea, and Other Countries:** NSF has held a series of bilateral workshops with these countries. It also has co-organized and participated in the International Dialogue on Responsible Development of Nanotechnology R&D series. NSF is a sponsor of the Materials World Network, which supports international collaborations in materials research, and which includes a focus on nanotechnology. It also participates in various other international activities (e.g., of the International Organization for Standardization—ISO—and the Organisation for Economic Co-operation and Development—OECD) described elsewhere in this report.
- **USDA/FS, American Forest & Paper Association (AF&PA):** As part of its growth strategy, the FS has established a public-private linkage with the American Forest and Paper Association Agenda 2020 Technology Alliance to develop a common and prioritized agenda for advancing nanotechnology within the forest products industry. This common agenda meets the needs of both the agency and the private sector. Formation by the forest products industry sector of a Cooperative Board for Advancing Nanotechnology (CBAN) in cooperation with the National Nanotechnology Initiative has been critical for establishing a forum to achieve this common agenda. The USDA FS participates in the AF&PA's CBAN by serving as the Federal nanotechnology liaison and working with industry to craft a nanotechnology agenda mutually supported by the forest products industry, Federal Government, and universities, and to carry out research, development and deployment of the agenda.
- **USDA/FS, Purdue University:** The FS growth strategy includes bringing universities into its public-private linkage by creating a virtual center for forest-based nanomaterials research and development. The FS has placed a scientist at the Birck Nanotechnology Center at Purdue University and is looking to establish a research presence and joint nanotechnology research projects with other universities such as the University of Tennessee-Knoxville and the Institute of Paper Science and Technology at the Georgia Institute of Technology.
- **USDA/FS, International Union of Forestry Research Organization (IUFRO):** Forest Service R&D organized two nanotechnology sessions at the 2007 IUFRO Division 5 Forest Products conference in Taiwan. There were over 400 attendees at this international conference.

[31] See further discussion of the NRI and NNI member agencies collaborations on p. 23.

Goal 2: Foster the transfer of new technologies into products for commercial and public benefit

The NNI has a number of activities uniquely targeting technology transfer and commercialization, e.g., workshops to gain input from industry and the academic community, SBIR and STTR programs to fund innovations in small businesses, and forefront research infrastructure for use by all nanotechnology researchers, including those from industry. Some positive results from these efforts are now evident.

Coordinated Interagency Activities Contributing to Goal 2

- **All NNI Member Agencies:** The NNI member agencies continue to convene workshops to discuss opportunities and priorities for nanotechnology research in specific sub-fields. Industry participants are invited to provide input and can learn about NNI-funded research that may be of interest to their companies. For instance, the NNI member agencies are currently organizing a series of workshops to address research priorities in specific areas of nanotechnology-related environmental, health, and safety research.

- **NIH/NCI, NIST, FDA:** NCI's Nanotechnology Characterization Laboratory (NCL) evaluates the safety and efficacy of nanotechnology-based cancer therapies and diagnostics to accelerate their translation into clinical applications. The NCL was formed and is funded by NCI but collaborates through interagency agreement with NIST and the FDA. The FDA provides input to the NCL on the type of testing needed to evaluate nanomaterials for regulatory review, and NCL data inform the FDA on which nanoparticle properties contribute to safety and toxicity. To date, the NCL has characterized over 125 nanomaterials intended for clinical cancer applications and contributed to the development of voluntary consensus standards for nanoparticle biocompatibility testing.

  NIST provides state-of-the-art instrumentation and expertise to determine the best measurement tools, protocols, and analysis algorithms for physical characterization of nanoparticles. NIST has issued its first reference standards for nanoscale particles targeted for the biomedical research community. The three new materials, gold spheres nominally 10, 30, and 60 nanometers in diameter were developed in cooperation with the NCL; the study was funded by NCI. These new nanoscale gold particles have been extensively analyzed by NIST scientists to assess particle size and size distribution by multiple techniques for dry-deposited, aerosol, and liquid-borne forms of the material. Additional technical and ordering information for the new NIST nanoparticle reference materials is available at https://srmors.nist.gov for Reference Materials 8011, 8012, and 8013.

- **NSF, NIST, DOD, DOE, USDA/FS:** Research on manufacturing at the nanoscale, or "nanomanufacturing," will be key to the large-scale application of nanotechnology innovations for commercial and public benefit. The NNI places a special emphasis on nanomanufacturing research as one of its eight program component areas. Several workshops have been conducted to help guide the NNI nanomanufacturing research agenda and coordinate it with industry; several more are planned for the near future. Reports from these workshops are posted on the NNI website, http://www.nano.gov.

- **DOD, NASA, and Other Mission Agencies:** The government is acting as the first customer for many innovative applications of nanotechnology. For example, DOD has led the way in development of electronics and sensing applications of nanotechnology, as well as in development and deployment of specialized coatings, e.g., to reduce wear and maintenance costs on moving parts in the U.S. Navy

fleet. NASA has led in the development of nanotechnology-enabled sensors, some of which are already flying in NASA spacecraft.

- **All NNI Member Agencies Participating in SBIR/STTR Programs:** SBIR/STTR awards aid in stimulating the development and commercialization of nanotechnology-enabled innovations. Between 2004 and 2007 NNI participating agencies have funded over $290 million in SBIR Program awards and STTR Program awards for nanotechnology R&D. The 21st Century Nanotechnology R&D Act calls for the National Science and Technology Council to develop a plan to utilize Federal programs such as the SBIR and STTR programs to promote commercialization of nanotechnology. The NNI plan essentially has been to encourage agencies to fund nanotechnology research through those programs, both through specific nanotechnology SBIR and STTR solicitations (as has been the case at NIH) and through non-nanotechnology-specific solicitations. As an example of the latter approach, a few years ago several agencies put out SBIR solicitations directed at addressing the need for advanced manufacturing research. Many of the successful proposals that were submitted to NSF and other agencies in response to that manufacturing R&D solicitation were nanotechnology-based proposals.

The latter example above is an important indicator of why the nanotechnology investment in the Federal Government continues to grow. Nanotechnology is now at the cutting edge of many traditional fields of science and technology. Fields as diverse as catalysis, cancer research, and composites manufacturing are looking to the ability to control matter at the nanoscale as key to future progress.

Individual Agency Activities Contributing to Goal 2

- **DOE:** The Department of Energy supports nanoscience technology transfer, industrial activity, and commercialization through the Office of Fossil Energy and the Office of Energy Efficiency and Renewable Energy; the latter includes a planned increase in nanomanufacturing activity in 2009.
- **NASA:** The agency continues to focus on the application of nanotechnology to space exploration. NASA's particular interests are related to applications for structures and devices that function in the extreme environments of space (e.g., radiation and wide temperature fluctuations). Investments are focused on (1) high-strength, lightweight, and multifunctional materials; (2) devices and sensor suites; and (3) radiation-resistant and fault-tolerant systems capable of sustained performance under extreme environments.
- **NIST:** Innovative analytical tools and methods under development at NIST will enable faster and more accurate characterization of the properties of nanomaterials, assessment of the performance and reliability of such materials in applications, and identification of potential EHS issues. New NIST instrumentation, metrology tools and techniques, and standards will benefit industry and promote commercialization and technology transfer. Examples range from new methods for measuring mechanical properties of nanoscale structures such as tensile strength, to a computing system for nanoscale magnetic modeling that has been utilized in projects leading to more than 650 peer-reviewed research publications, to the installation of the world's first commercial helium ion microscope, which provides greater depth of field and finer edge resolution than possible with conventional scanning electron microscopes.
- **NSF:** NSF has a series of research and education programs funding university-industry interactions in nanotechnology, including Grand Opportunities for Academic Liaison with Industry (GOALI), Partnerships for Innovation (PFI), NSF-Nanoelectronics Research Initiative Graduate Student and Postdoctoral Fellow Supplements to NSF Centers in Nanoelectronics, and Industry-University

Cooperative Research Projects (IUCRP). The National Nanotechnology Infrastructure Network and Network for Computational Nanotechnology user facilities (NNIN and NCN) have more than 1000 industry users per year. The Nanoscale Science and Engineering Centers and Materials Research Science and Engineering Centers (NSECs and MRSECs) have industrial partners and industry experts on their advisory boards.

- **USPTO:** USPTO's Class 977 is the first fully expanded patent-related nanotechnology classification schedule developed by any major intellectual property office in the world. The agency continues to provide its patent examiners both enhanced in-depth technical training on the state of the art in nanotechnology and greater access to nanotechnology technical information to improve their knowledge base. As a result of this on-going training initiative and targeted hiring, the USPTO has trained a subset of patent examiners across all technology disciplines who serve as points of contact to assist other examiners with nanotechnology issues related to patent examining.

Engagement with Groups and Activities External to the NNI, Including International Activities, Contributing to Goal 2

- **NNI Member agencies, American National Standards Institute (ANSI):** Working with ANSI, NNI member agencies support the development of international standards for nanotechnology. Such standards will be critical to future commercialization activities. The NNCO Director chairs the ANSI U.S. Technical Advisory Group (TAG) to the International Organization for Standardization (ISO) Technical Committee on Nanotechnologies (ISO TC 229). NNI agencies are providing financial support to the ANSI's Nanotechnology Standards Panel (ANSI-NSP) and the ANSI-accredited TAG that represents the United States on ISO TC 229. The United States is the convenor for the ISO TC 229 Working Group on EHS aspects of nanotechnology.

- **NNI Member Agencies, Industrial Groups:** Industrial sector groups assist in exchanging information on NNI research activities and industry needs and in leveraging funds for cooperative R&D. Industry liaison groups with the electronics, forest products, and chemical industries and with the industrial research management community are continuing their activities, and formation of comparable groups with other sectors (e.g., the construction industry) is under consideration. One successful example is the collaboration between NSF, NIST, and the industry-led Nanoelectronics Research Initiative (NRI), where industry and government representatives collaborate in reviewing proposals and in supporting precompetitive research.[32] Another planned activity is NIH's "NanoHealth and Safety Enterprise," which is envisioned as a partnership with other Federal agencies, private industry, and international partners to address research needs for safe development of nanoscale materials and devices.[33]

  As a second example, NIST and USDA/FS sponsored a cross-industry nanomanufacturing workshop in May 2008 with the endorsement of the NSET Subcommittee and participation from the forest products, automotive, chemical, pharmaceutical, aerospace, semiconductor, and food industries. The objective of the workshop was to identify common problems and common solutions specific to nanotechnology, manufacturing processes, and performance of nanomaterials in commercial products within these widely different industries.

[32] See further discussion of the NRI and NNI member collaboration on the next page.
[33] See the section on Goal 4 below for more details on the NanoHealth and Safety Enterprise.

- **NNI Member Agencies, Nanoelectronics Research Initiative (NRI)**: The NRI is a partnership among industry, state and Federal governments, and academia to support world-class, discovery-based research in nanoelectronics with major participation from the Semiconductor Research Corporation (which is affiliated with the Semiconductor Industry Association). The goal of this program is to demonstrate novel yet practical computing devices capable of replacing conventional chip technology by 2020. The long-term research goals were established after a joint NNI-semiconductor industry workshop in October 2003, followed by a memorandum of understanding (MOU) signed between NSF and SRC in 2004 for joint activities with Nanoscale Science and Engineering Centers (NSECs) and small-group Nanoscale Interdisciplinary Research Teams (NIRTs). Building on the long-term cooperation between NNI member agencies and the electronics and semiconductor industries, NSF and the NRI are co-funding supplemental grants for NRI-related research at existing NSF nanoscience centers, i.e., the NSECs, MRSECs, and the NCN. The goal in making this joint investment with NSF is not only to complement the work going on in the NRI centers, but also to leverage the research taking place in the NSF centers, with the NRI program gaining from the knowledge being created in the NSF centers as a whole, and the NSF centers gaining from the industry involvement through NRI.

  In 2007, NIST joined in this effort by establishing a pilot program to accelerate research and innovation in nanoelectronics through a public-private partnership. NIST has signed a cooperative agreement, renewable for up to five years, which provides $2.76 million annually from NIST, plus matching funds from each of the six NRI partners, for a total of over $10 million. The funds are combined and competitively awarded for research at U.S. universities to meet industry's long-term needs. The research is focused around four multi-institution centers, with 35 participating universities in 20 states. A number of NRI researchers are now collaborating with NIST researchers and using NIST's world-class nanoscale measurement and fabrication facilities.

- **NNI Member Agencies, Forest Products Industry:** USDA/FS, USDA/CSREES, NSF, the Technical Association of the Pulp and Paper Industry (TAPPI), and the Forest Products Society (FPS) co-sponsored the 3rd annual International Conference on Nanotechnology for the Forest Products Industry (June 25–27, 2008, St Louis, MO). Initiated in 2006 by the USDA/FS, USDA/CSREES, and AF&PA Agenda 2020 Technology Alliance, this three-day conference had well over 150 national and international attendees from industry, academia, and national laboratories. This was the largest gathering to date of forest products professionals and decision-makers focused on nanotechnology business, nanomanufacturing, and applications R&D.

- **NIST, NSF, NIOSH, DOE's Oak Ridge National Laboratory:** These institutions organized a new SPIE Conference, "Instrumentation, Metrology, and Standards for Nanomanufacturing," to address interoperability; instrument integration; information management; and environmental, health, and safety monitoring and metrology in nanomanufacturing.

- **NIST, State Nanotechnology Organizations:** Representatives from over 60 organizations interested in nanotechnology commercialization met on February 21, 2008, at the "Measuring Nano" workshop convened by NIST and the Colorado Nanotechnology Alliance. Through a combination of laboratory tours and research seminars, attendees were introduced to the latest advances in small-scale materials characterization, advanced optical and electronic measurements, and nanoscale device fabrication techniques. Attendees met with NIST scientists to discuss mechanisms for collaboration and plan follow-up activities.

On April 8, 2008, NIST hosted a Technology Transfer Showcase in Gaithersburg, Maryland, co-sponsored by the Maryland Technology Development Corporation and the Tech Council of Maryland. Speakers covered a wide range of nanotechnology research topics ranging from characteristics of delivery systems for nanomedicine to single-molecule mass spectrometry, as well as the role of nanotechnology in building and construction and electronics. The meeting was attended by business executives, entrepreneurs, investors, and government researchers and development officials interested in commercializing recent research advances in nanoelectronics, nanofabrication, and nanometrology.

NIST has signed a memorandum of understanding with the College of Nanoscale Science and Engineering of the University at Albany, State University of New York, laying the groundwork for future cooperative efforts to develop science and technology for measuring materials at the nanometer scale as well as to create new standards for nanomanufacturing.

- **NIST, NASA, International Standardization Organization (ISO):** In March 2008 NIST and NASA published a detailed guide for making essential measurements on samples of single-walled carbon nanotubes (SWCNTs).[34] The new guide constitutes the current best practices for characterizing one of the most promising and heavily studied of the new generation of nanoscale materials. The techniques described in the guide were proposed as the basis for international standards for nanotube characterization. A collaborative effort that includes the United States, China, Japan, and Korea has been initiated under the auspices of ISO to develop these techniques into standards that will help ensure that uniform characterization metrics are used in buying and selling nanotubes.

  In February 2008, NIST hosted an ISO-organized workshop to identify short- and medium-term documentary standards needs for nanotechnologies and the underlying measurement solutions needed to facilitate the movement of nanotechnology innovations from research to a market environment while ensuring health and environmental safety. The workshop brought together over 70 experts representing various technical committees within ASTM International, the International Electrotechnical Commission (IEC), the Institute of Electronics and Electrical Engineers-Standards Association (IEEE-SA), ISO, Semiconductor Equipment and Materials International (SEMI), the OECD Working Party on Manufactured Nanomaterials, along with representatives from 11 national metrology laboratories and the Versailles Agreement on Materials and Standards.[35]

- **NSF, Industry Organizations:** NSF has continuous contacts with industry organizations in the chemical industry (e.g., Council of Chemical Research), the electronics industry (e.g., Semiconductor Research Corporation), business (Industrial Research Institute), and other areas.

- **NSF, NIST, DOD, Industry, ISO:** The NSF-sponsored National Nanomanufacturing Network (NNN) has launched InterNano, an open-source information clearinghouse for the nanomanufacturing R&D community.[36] InterNano's online resources include a nanomanufacturing process database and a nanomanufacturing resource library. Access to these resources is facilitated by the InterNano taxonomy for nanomanufacturing, which will be used as the basis for a U.S. contribution to the development of a new international standard. The NNN is actively participating in the ISO TC 229 effort to develop standardized terminology for nanomanufacturing processes.

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[34] S. Freiman, S. Hooker, K. Migler and S. Arepalli (eds.). 2008. Measurement Issues in Single Wall Carbon Nanotubes. NIST Special Publication 960-19.
[35] For more information see http://www.iso.org/nanotech-workshop.
[36] http://www.internano.gov.

- **USDA/CSREES, Food Industry, Netherlands, Canada:** USDA/CSREES, the Institute of Food Technologists, the Netherlands Office for Science & Technology, and the Canadian Advanced Food and Materials Network co-sponsored the third International Food Nanoscience Conference (June 27-28, 2008, New Orleans, LA). This two-day conference attracted more than 150 multinational participants from the food industry, academia, government, and other organizations. Nanotechnology applications in food safety detection, traceability, food ingredients, food processes, food packaging, and contact materials were highlighted. EHS, ethical, and broad societal issues were addressed.

- **USPTO, Patent Stakeholders:** The USPTO hosts an annual nanotechnology Customer Partnership meeting so that USPTO officials and patent stakeholders can confer on a regular basis to share concerns and information related to the patenting of nanotechnology. In 2009, the USPTO will host its seventh annual nanotechnology Customer Partnership meeting.

- **USPTO, Trilateral Offices (USPTO, European Patent Office [EPO], Japanese Patent Office [JPO]):** The USPTO is working with the European and Japan Patent Offices (the Trilateral Offices) to develop a common International Patent Classification (IPC) scheme for nanotechnology based upon the USPTO schedule. This effort includes the consideration of a harmonized definition of nanotechnology as it relates to patent examination. The agency completed an expansion of this single subclass digest by developing a comprehensive nanotechnology cross-reference art collection classification (Class 977, Nanotechnology). Class 977 includes 263 subclasses, definitions, and search notes.

  The Trilateral Offices (USPTO, EPO, JPO) are also exploring the harmonization of examination practices in the nanotechnology art. The USPTO proposed an exchange of information, including (1) a listing of search resources for nanotechnology inventions, (2) examination-quality and training initiatives; (3) consideration of rejections based on "obviousness/non-inventive step" as they relate to a change in size of what is known in the prior art; and (4) evaluation of evidence submitted to establish "unobviousness/inventive step" with respect to size and special property, function, or effect specifically attributed to size. The Trilateral Offices started an exchange of information in the fall of 2007 and expect to continue this dialog on these issues into 2009.

Goal 3: Develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology

Significant progress is being made on all three aspects of Goal 3. With respect to education and workforce development, education is among the chief objectives of NNI-funded university research. In addition, specific programs targeted at K–16 education, educating the public about nanotechnology, and improving nanotechnology curricula in our schools and universities have been initiated and are growing in scale and reach. Details are provided in the following text. The extensive network of research centers, user facilities, and other infrastructure for nanotechnology research, which was a key element of the original NNI strategy, is now largely complete.[37]

[37] See a detailed discussion of the U.S. NNI infrastructure in the NNI Supplement to the President's FY 2008 Budget, http://www.nano.gov/NNI_08Budget.pdf, including a map that shows the location of all the centers, networks, and user facilities (p. 21) and a list of participating academic institutions and national laboratories (pp. 29–33).

Coordinated Interagency Activities Contributing to Goal 3

- **All NNI Member Agencies:** Some of the most interesting and potentially beneficial applications of nanotechnology are emerging at the intersections of traditional disciplines. Therefore, the NNI has created strong incentives for interdisciplinary research at our major research institutions. A new cadre of multidisciplinary researchers is emerging, trained in multiple fields previously considered highly distinct such as biology, chemistry, and solid state physics. While there remains a strong appreciation for the importance of building a solid foundation for researchers of the future in the traditional disciplines of science and engineering, NNI-funded networks, centers of excellence, and user facilities have helped to create a new culture of interdisciplinary research and a new generation of multidisciplinary researchers.
- **All NNI Member Agencies:** As indicated in the introductory paragraph to this goal section, the network of research centers, user facilities, and other infrastructure is now largely complete. This mature infrastructure serves to accelerate nanotechnology research and development and enables researchers from across various sectors to broadly leverage their interdisciplinary intellectual and technological capital. NNI agencies are encouraging industrial interaction with NNI-funded research centers, and they are promoting broad access to the NNI user facilities by all sectors, including small businesses. While emphasis in the near future will be on maximizing the utility and utilization of the substantial infrastructure already in place, the agencies will also consider possible new infrastructure needs for the longer term. The effectiveness of this investment is enhanced through collaboration among the centers funded by the various agencies (NSF, DOD, DOE, and NIH).
- **DOE, USDA, NIH:** As a way of promoting awareness and utilization of the NNI infrastructure, several meetings organized or supported by USDA have recently been held in proximity to, and have included tours of and presentations at, the Nanoscale Science Research Center user facilities that have been established by DOE. These included the 2007 International Conference on Nanotechnology for the Forest Products Industry, supported by the USDA Forest Service and held in Knoxville, Tennessee, with activities at the Center for Nanophase Materials Sciences at Oak Ridge National Laboratory. Another example is a meeting of the USDA/CSREES nanotechnology grantees in Davis, California, including a half-day at the Molecular Foundry at Lawrence Berkeley National Laboratory. The mutual benefit of incorporating NSRC visits into these workshops was apparent, and similar visits to other DOE NSRC facilities for subsequent meetings are being explored. DOE and NIH representatives have also met on several occasions to discuss their respective nanotechnology activities, particularly with regard to availability and operations of user facilities, as well as public-private partnerships.
- **DOL, DOEd, All Other NNI Member Agencies:** As recommended by several external advisory groups, the NNI has reached out to the Department of Labor (DOL) and the Department of Education (DOEd); both agencies have joined the NSET Subcommittee and are now engaged in discussions with other NNI participating agencies about how to best address workforce and education issues associated with the successful development of nanotechnology. For example, DOEd is working with NSF to plan a workshop (tentatively scheduled for March 2009) on possible future nanotechnology education partnerships.

Individual Agency Contributions to Goal 3

- **DOE:** The Department of Energy has completed its suite of five Nanoscale Science Research Centers (NSRCs), major user facilities that are available to all researchers based on competitive peer review.

The NSRC program has been recognized by major departmental awards for project management, and also has received external accolades. The Molecular Foundry at Lawrence Berkeley National Laboratory was honored with the Secretary of Energy's Excellence in Acquisition Award. This facility had previously received U.S. Green Building Council Leadership in Energy and Environmental Design (LEED) Gold certification and had been named the first-place winner of the Sustainable Buildings Industry Council's 2007 *Beyond Green*™ High-Performance Building Award. In addition, the Center for Integrated Nanotechnologies at Sandia and Los Alamos National Laboratories received the Secretary of Energy's Award of Achievement in Project Management. All five of the NSRCs are now in operation and available to external users.[38]

- **DOEd:** The Department of Education has awarded three grants totaling $1.3 million[39] from Congressionally directed funds to support teacher training and development of curricula and laboratories for introducing students to nanotechnology at the K–12 and undergraduate levels.
- **DOL:** The Department of Labor has awarded a $1.5 million Advanced Manufacturing Industry Grant to the International Association of Nanotechnology[40] under the President's High Growth Job Training Initiative. The grant funds training to equip California workers for employment in the emerging nanotechnology industry.
- **NIST:** NIST opened its advanced nanofabrication facility, the NanoFab, to external users in May 2007; by May 2008, over 160 external users from government, academic, and industrial laboratories had accessed the facility. Organizationally within the Center for Nanoscale Science and Technology, the NanoFab provides state-of-the-art equipment and expert training for nanofabrication and characterization, as well as access to specialized measurement tools and expertise residing in NIST's extensive measurement laboratories. Access to the NanoFab is granted via a competitive proposal process on a fee-based, shared-use basis.[41]

  NIST is helping to train the next generation of experts in nanoscale measurement science through the Center for Nanoscale Science and Technology's Cooperative Research Program with the Center for Integrated Nano Science and Engineering at the University of Maryland. In addition to supporting about a dozen postdoctoral researchers working under the guidance of NIST staff scientists, this program supports national outreach and education efforts.
- **NSF:** The National Science Foundation has educational programs for nanotechnology from kindergarten to graduate school levels that support about 10,000 students and teachers each year; NSF includes educational impact among the key review criteria for its proposals. As a result of NSF efforts and requirements, thousands of undergraduate and graduate students have received training in nanoscale science and technology, providing the pipeline for nanotechnology workers and researchers that industry needs to commercialize the results of basic research in nanoscale science and technology.

  A number of initiatives are underway specifically to improve nanotechnology education, curricula, and workforce development. These include the National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT), the Nanoscale Informal Science Education (NISE) Network, and

[38] For further information see http://www.nano.energy.gov.
[39] These funds are not reflected in Table 4.
[40] These funds are not reflected in Table 4.
[41] For further information see http://cnst.nist.gov/nanofab/nanofab.html.

the Nanotechnology Undergraduate Education (NUE) programs. Details are available in the NNI Supplement to the President's Budget for FY 2008.

Goal 4: Support responsible development of nanotechnology

The NNI has made significant progress towards the goal of supporting responsible development of nanotechnology. Funding for nanotechnology-related EHS research in particular has more than doubled, from $35 million in 2005 to $76 million in the 2009 request. This is only counting the narrowly defined *primary purpose* EHS R&D. If related research that is critical to the primary purpose EHS research is included (e.g., instrumentation and metrology needed to correctly characterize the materials being used to conduct EHS research, so properties of the materials being tested are known), the figure for 2009 would be well over $100 million. The NNI agencies have reached a strong consensus on a comprehensive strategy to move these investments forward effectively, in line with the roles and responsibilities of the respective agencies involved. The NNI also maintains a strong portfolio of research on ethical, legal, and other societal implications of nanotechnology, along with support for innovative approaches to nanotechnology education at all levels, from K-12 though graduate education and public outreach.

Coordinated Interagency Activities Contributing to Goal 4

- **All NNI Member Agencies:** EHS research planning is a major activity for the NNI. In August 2007, the National Science and Technology Council's NSET Subcommittee published a draft report for public comment prepared by its NEHI Working Group entitled *Prioritization of Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials*[42]. In February 2008, the NEHI Working Group completed a comprehensive *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research*. [43] This was the culmination of two years of intensive work, including a detailed review of individual EHS research projects funded by the NNI agencies in 2006, which was used as a guide to help identify gaps in the research portfolio compared to the NNI designated priority research areas.

- **All NNI Member Agencies:** NNI agencies are organizing a series of workshops aimed at obtaining input from the public and the research community on each of the five major categories of EHS research needs outlined in the February 2008 *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research.* These workshops will also facilitate coordination of EHS-related activities among agencies participating in the NEHI Working Group. NEHI Working Group participation continues to expand. For example, the USGS, which joined the NSET Subcommittee and the NEHI Working Group in 2007, now has contributed to various NEHI Working Group documents, as well as to planning activities of the NSET Subcommittee. This involvement has informed the growth and planning of USGS activities related to nanotechnology, particularly related to EHS issues.

- **All NNI Member Agencies, CPSC:** Regulatory and research agencies have been collaborating closely as the regulatory agencies formulate their respective approaches to regulation of nanotechnology-related products, informed by EHS research conducted by the research agencies. For example, staff members from CPSC have met with staff at NIST, EPA, FDA, and NIOSH to identify areas of mutual interest and collaboration. CPSC has signed an MOU with NIST to review nanotechnology-based flame retardants in various products. The CPSC staff is also developing an interagency agreement with NIOSH to conduct laboratory investigations of nanomaterials emissions from selected

[42] http://www.nano.gov/Prioritization_EHS_Research_Needs_Engineered_Nanoscale_Materials.pdf.
[43] http://www.nano.gov/NNI_EHS_Research_Strategy.pdf.

consumer products. CPSC participates in the NSET Subcommittee, the NEHI Working Group, and the National Toxicology Program (NTP). Participation in these groups and activities fosters communication between CPSC staff and the staff of various other Federal agencies. Through this participation, CPSC staff members learn about health effects data and the best available practices for the regulation of nanomaterials. These interactions also promote responsible research and development of nanomaterials that can be used in consumer products.

- **All NNI Member Agencies, NIOSH:** NIOSH continues to collaborate with and leverage resources from other agencies. Specifically, NIOSH is coordinating its toxicological and exposure studies with NTP, collaborating with NIST on the development of reference nanomaterials for EHS work, and exploring collaborations with CSPC. In 2008 and 2009, NIOSH will coordinate interagency activities in the Human and Environmental Exposure Assessment category of research in accordance with the NNI *Strategy for Nanotechnology-related Environmental, Health, and Safety Research*.

- **EPA, DOE, NIH, NIOSH, NSF:** Two joint interagency solicitations addressing potential environmental and health implications of nanotechnology continue. One (led by EPA, with NSF and DOE participation)[44] addresses environmental implications of nanotechnology, while another (led by NIH, with EPA and NIOSH)[45] focuses on human health implications. Awards from the most recent EPA-led solicitation, focusing on fate, transport, and exposure, are expected to be made in 2008.

- **EPA, FDA, NIOSH:** As the NNI EHS research strategy evolves, coordinated activities to address the breadth of EHS issues are proceeding at an accelerating pace. A Food and Drug Administration (FDA) task force released a report in 2007 addressing scientific questions related to the application of its regulatory authorities to nanotechnology-enabled products. EPA issued a white paper on nanotechnology in 2007, and has initiated a Nanoscale Materials Stewardship Program under the Toxic Substances Control Act to gather and develop information from manufacturers, importers, processors, and users of engineered chemical nanoscale materials. NIOSH continues to update its guidance document on best practices for safe handling of nanomaterials in the workplace, and it has posted a draft document providing interim guidance on medical screening of workers potentially exposed to engineered nanoparticles.[46]

- **NSF and EPA**: In 2008, the NSF was the lead agency (in collaboration with EPA) in funding two new national Centers for the Environmental Implications of Nanotechnology (CEIN) for a period of five years in response to an identified national need. NSF plans to form a network around these new centers in 2009 with collaboration from EPA and other agencies.

- **NTP, led by NIH/NIEHS with participation from many other agencies, e.g., FDA, EPA, and several other NIH institutes:** The NTP is actively pursuing the research agenda outlined in its Nanotechnology Safety Initiative.[47] This involves planning and conducting toxicology research across the classes of nanoscale materials, including nanoscale titanium dioxide and zinc oxide, quantum dots, fullerenes and multiwalled carbon nanotubes, silver, and gold (NIST reference standards).

[44] http://es.epa.gov/ncer/rfa/2007/2007_star_nanotech.html.
[45] http://grants.nih.gov/grants/guide/rfa-files/RFA-ES-06-008.html.
[46] See http://www.cdc.gov/niosh/topics/nanotech/safenano/.
[47] http://ntp.niehs.nih.gov/go/nanotech.

Individual Agency Contributions to Goal 4

- **CPSC:** CPSC has posted on its website a general statement for the public about its approach to regulating nanomaterials.[48] A contractor for CPSC has completed a literature review of nanomaterials that may be used as flame-retardant (FR) chemicals. The report focuses on the physico-chemical properties of the FR chemicals and also reviews potential exposure and health effects of these compounds. The report will be posted on the CPSC website for public comment.

- **EPA:** EPA has initiated a Nanoscale Materials Stewardship Program under the Toxic Substances Control Act (TSCA) to gather and develop information from manufacturers, importers, processors, and users of engineered chemical nanoscale materials. The information gathered through the stewardship program will further EPA's scientific understanding of potential risks and benefits of these nanoscale materials.

  In 2007 the EPA Office of Research and Development held a public meeting for the external peer review of its Nanomaterial Research Strategy.[49] EPA has received comments on this document from the general public and from the peer review panel; the strategy document is currently under revision to address these comments. The final strategy is expected to be issued in late calendar year 2008. The strategy outlines the EPA's research role in nanotechnology and where and how the agency will leverage efforts with other agencies and stakeholders to maximize resources and achieve goals.

- **FDA:** The FDA Nanotechnology Task Force (NTF) released a report in 2007 that conveys consideration of and recommendations for science needs and regulatory policy related to nanoscale material use in FDA-regulated products.[50] Follow-on activities on the basis of the NTF report findings are now occurring within the FDA's individual product review functions, with cross-FDA coordination occurring through the FDA NTF and the FDA Nanotechnology Interest Group. FDA activities in support of regulatory decisions also include participation in the NTP Nanotechnology Safety Initiative (described above), as well as a limited amount of additional intramural research within FDA into nanoscale titanium dioxide and silver. FDA has established a portal website for all of its nanotechnology-related activities.

  NIOSH: NIOSH will continue increasing its investments in nanotechnology R&D related to worker health and safety, in close coordination with other agencies. The NIOSH budget request continues steady investment for 2009. This investment allows for continuing intramural and extramural projects directed to address critical research gaps around occupational safety and health of nanotechnology and nanomaterials. Specifically, in 2009 there will be emphasis on the development of standard methods for characterization of airborne nanoparticles in the workplace environment and their aerosol generation potential, and on further toxicological studies of carbonaceous and metal nanomaterials and characterization of workplace exposures to those nanomaterials.

  In 2008, NIOSH plans to update its most popular guidance document on nanotechnology occupational safety and health, *Approaches to Safe Nanotechnology: An Information Exchange with NIOSH*,[51] using information collected through its Nanotechnology Research Field Team program.

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[48] http://www.cpsc.gov/library/cpscnanostatement.pdf.
[49] http://es.epa.gov/ncer/nano/publications/nano_strategy_012408.pdf.
[50] The NTF report and additional information regarding FDA activities on nanotechnology can be found at http://www.fda.gov/nanotechnology.
[51] http://www.cdc.gov/niosh/topics/nanotech/safenano/.

In 2008, NIOSH assessed the state of knowledge regarding occupational safety and health aspects of nanotechnology and conducted a critical gap analysis of research needs based on the concepts outlined in *Progress Toward Safe Nanotechnology in the Workplace.*[52] An updated draft *Strategic Plan for NIOSH Nanotechnology Research* was released in March 2008[53] and will be externally peer-reviewed later in 2008.

In December 2007, NIOSH posted for public review a draft document providing interim guidance concerning the medical screening of manufacturing and industrial workers potentially exposed to engineered nanoparticles.[54] The guidance was developed to generate discussion, fill current knowledge gaps, and provide interim recommendations until further scientific information becomes available. In 2008 this document will be externally peer-reviewed.

In 2008, NIOSH began developing a series of brochures and fact-sheets describing NIOSH recommendations and efforts in nanotechnology. The first brochure in this series is *Safe Nanotechnology in the Workplace: An Introduction for Employers, Managers, and Safety and Health Professionals*. [55]

- **NIST:** NIST is taking the lead in addressing metrology needs for nanotechnology-related EHS research. It is providing or developing (1) new measurements to support toxicology studies; (2) materials and methods to enable environmental and health-effect studies, including reference materials and documentary standards; (3) methods to measure nanomaterials in the environment, including in water, soil, and biota; and (4) methods to characterize the physical and chemical properties of nanomaterials. In June 2008, NIST hosted a workshop on Environmental, Health and Safety Issues in Nanomaterials to assess measurement needs and solutions for addressing potential EHS impacts of nanotechnology. The workshop gave attendees an opportunity to hear early results of the NIST United States Measurement System (USMS) Nano EHS assessment and to inform strategic decision-making and research prioritization. NIST also led in organizing the September 2007 NNI Workshop on Standards for EHS Research Needs for Engineered Nanoscale Materials, which brought together risk assessment and regulatory representatives from government, academia, and industry to identify materials needed to enable nanomaterial risk management decision-making processes for the regulatory community and industry.
- **NIST**: In its role as the national measurement institute, NIST is building on its expertise and experience to develop dimensional metrology and characterization methods and standards for nanotechnology-related EHS in the United States. Work to develop analytical methods for quantifying the type and amount of nanomaterials in biological matrices, the environment, and the workplace is underway and planned to expand considerably in 2009 (with the planned funding increase). Focused efforts will evaluate the scope and suitability of technologies to measure biological effects of exposure to nanomaterials or nanoparticles. The development of reference materials, nanomaterial characterization techniques, and methods to validate toxicity testing are all part of this program.

[52] http://www.cdc.gov/niosh/docs/2007-123/.
[53] http://www.cdc.gov/niosh/topics/nanotech/strat_plan.html.
[54] http://www.cdc.gov/niosh/review/public/115/.
[55] These brochures and fact sheets are available on the web at http://www.cdc.gov/niosh/docs/2008-112/pdfs/2008-112.pdf and at http://www.cdc.gov/niosh/whatsnew.html.

NIST is developing the measurement science for quantifying the release of nanomaterials from combustion and aging of products that contain nanoparticles. These data are critical to understanding in-use and end-of-life EHS exposure issues for products that utilize nanomaterials. NIST is also applying its expertise in life-cycle-assessment (economic) modeling and in nanomaterials-based flame retardants to develop sustainability tools for the industries that develop fire-safe products.

- **NRC:** As a highly technical regulatory agency, the Nuclear Regulatory Commission (NRC) is monitoring developments in nanotechnology that are taking place in the NNI agencies as well as other Federal entities. Specific applications requiring near-term regulatory approval by the NRC have not been identified. As nanotechnology advances, specific applications within the NRC's scope of responsibility are expected.

- **NSF:** NSF supports fundamental research, infrastructure, and education in all aspects of "societal dimensions" of nanotechnology, including environmental, health, and safety (EHS); and ethical, legal, and social issues (ELSI). In EHS, NSF-sponsored research addresses the three sources (natural, incidental, manufactured) of nanoparticles and nanostructured materials in different environmental settings (air, water, soil, biosystems, and the work environment), as well as nonclinical biological implications. These topics are supported through programs in all NSF research directorates with a focus on new measurement methods and instrumentation for nanoparticle characterization and nanotoxicity, transport phenomena of nanoscale aerosols and colloids, interaction of nanomaterials with cells and living tissues, safety in nanomanufacturing, physico-chemical-biological processes of nanostructures dispersed in the environment, separation of nanoparticles from fluids, development of user facilities, and educational programs supporting EHS issues. The safety of manufacturing nanoparticles is being investigated at several Nanoscale Science and Engineering Centers and at several nodes of the National Nanotechnology Infrastructure Network.

  With respect to ELSI, NSF supports research on economic, social, legal, ethical, and political implications of nanotechnology development over short-term and long-term horizons. It includes (1) research on patterns in U.S. and global diffusion and distribution of nanoscale research and technology, (2) testing of methods for building capacity for anticipatory governance of nanotechnology development, (3) methods for improved integration of public perceptions of risk and formal and informal science education efforts, (4) research on the social and cultural variability in different publics' understanding of nanotechnology-related environmental and health risks, and (5) continued monitoring of public values and beliefs as they relate to nanomaterials. NSF sponsors research on public perceptions of EHS risks and the values, beliefs, and practices that help shape these perceptions.

- **USDA/CSREES:** In the combined 2007 and 2008 solicitation of CSREES's Nanoscale Science and Engineering for Agriculture and Food Systems Program,[56] social science researchers are supported to address public perception and acceptance of nanotechnology applications in agriculture and food systems. As an example of this activity, CSREES recently released a series of four videos illustrating the potential applications of nanotechnology.[57]

- **USDA/FS:** Forest Service researchers are investigating the use and protection mechanism of low-loading nanodimensional silver and impregnated nanoclay tubes as environmentally safe wood

[56] See additional information on this CSREES program above under Goal 1.
[57] *Science of Small*: http://www.csrees.usda.gov/newsroom/partners/21/nanotechnology.html.

protectants. In addition, they are investigating self-assembly of nanopolymeric protectants for controlled release of fire retardants and biocides.

- **USGS:** The U.S. Geological Survey is gradually increasing its investment in research related to the environmental fate and effects of anthropogenic nanomaterials to close to $0.1 million,[58] building on its historical work on naturally occurring nanomaterials, including colloids and soot. Specifically, its research effort in nanoparticles includes projects addressing effects of these particles on aquatic biota, studies of microbially mediated production of quantum dots and other nanosized inorganic particles, and research on nanomaterials in wastewater treatment effluents. Several projects include nanoparticles as part of a more comprehensive examination of environmental sources and processes. The agency also collaborates with investigators funded through the EPA Star Program. In addition to investigating elemental selenium and tellurium nanoparticles, USGS is working on nanosilver, silicon carbide nanowires, and titanium dioxide quantum dots.

Engagement with Groups and Activities External to the NNI, Including International Activities, Contributing to Goal 4

- **All NNI Member Agencies, International Organization for Standardization:** International collaborations in nanotechnology standardization are progressing with strong NNI participation. The NNCO and several NSET Subcommittee member agencies represent the United States on the ISO Technical Committee on Nanotechnologies (ISO TC 229), and the United States leads the ISO TC 229 working group on EHS aspects of nanotechnology.
- **All NNI Member Agencies, OECD:** The OECD Working Party on Manufactured Nanomaterials (WPMN), part of the OECD Chemicals Committee and chaired by the United States, is implementing work in the following EHS areas:
  - Development of a database on human health and environmental safety research
  - Research strategies on manufactured nanomaterials
  - Safety testing of a representative set of manufactured nanomaterials
  - Manufactured nanomaterials and test guidelines
  - Cooperation on voluntary schemes and regulatory programs
  - Cooperation on risk assessment
  - The role of alternative methods in nanotoxicology
  - Exposure measurement and exposure mitigation

  The online database system holding details of completed, current, and planned international research on the safety of manufactured nanomaterials[59] will be launched and publicly available in 2009. The WPMN has conducted a review of current research programs, which also supports the identification of priorities and gaps. A sponsorship program has been launched where OECD members and industry will test 14 representative nanomaterials for a range of environmental, health, and safety endpoints to better characterize their risks. WPMN has also completed (1) a review of existing OECD harmonized test guidelines for chemical safety to determine their applicability for nanomaterials (including setting priorities for work to develop future guidelines), (2) an analysis of voluntary and regulatory initiatives in member countries, and (3) a report on exposure mitigation and exposure measurement in

[58] These funds are not reflected in Table 4.
[59] http://www.oecd.org/department/0,3355,en_2649_37015404_1_1_1_1_1,00.html.

occupational settings (which also includes recommendations for future work on this area with an aim of raising awareness and harmonizing approaches to exposure mitigation).

A second OECD working party, the Working Party on Nanotechnology (WPN)—formed under the Committee for Scientific and Technological Policy—is addressing broader issues such as economic impact, education and training, and public communication. WPN is also chaired by the United States.

- **CPSC, ANSI, International Life Sciences Institute (ILSI), ASTM International, International Council on Nanotechnology (ICON):** In addition to its interactions within the Federal Government via participation in the NSET Subcommittee and the NEHI Working Group (described above), CPSC further benefits from interactions with outside groups that are addressing issues associated with nanotechnology-enabled consumer products. These include ANSI, ILSI, ASTM, and ICON.
- **DOE, Japan, Russia:** Representatives from DOE have met with numerous international visitors in the past year to discuss respective programs in nanoscience and related areas. Visitors have included guests from Japan's National Institute for Materials Science and from governmental and related organizations in Russia.
- **EPA, Japan**: EPA has entered into collaborative research partnerships with Japan through which selected engineered nanomaterials will be studied: biological toxicity studies will be conducted by researchers in Japan, and fate/transport and ecological studies will conducted by EPA researchers. This approach is articulated in a *Draft Nanomaterial Research Strategy*[60] developed by the Office of Research and Development of the Agency and released by EPA for public comment in January 2008. The strategy builds on and is consistent with the foundation of scientific needs identified in the report, *Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials*, by the NEHI Working Group,[61] and on the EPA White Paper on Nanotechnology.[62] It is also consistent with the recently released NNI *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research.*
- **NIH, Other NNI Member Agencies, Private Industry, International Organizations:** The National Institute of Environmental Health Sciences (NIEHS) and the National Institute of Biomedical Imaging and Bioengineering (NIBIB) are co-leading the Trans-NIH Nano Task Force in developing a NanoHealth and Safety Enterprise Initiative that would employ state-of-the-art research technologies to examine the fundamental physicochemical interactions of engineered nanomaterials with biological systems at the molecular, cellular, and organ level. This investigative work would be supported by an informatics framework to identify cross-cutting design principles, and by training for the next generation of nanotechnology scientists. The NanoHealth and Safety Enterprise would comprise an integrated, interdisciplinary program that draws upon the expertise and interests of the NIH institutes and centers, in partnership with other agencies of the U.S. Government, private industry, and international partners, to address critical research needs for the safe development of nanoscale materials and devices.
- **NIOSH, OECD, European Commission:** In November 2007, the OECD Working Party on Manufactured Nanomaterials agreed to establish a NIOSH-led project to (1) exchange information on measuring and controlling exposures to nanomaterials, and (2) develop suggestions for further steps by

[60] http://es.epa.gov/ncer/nano/publications/nano_strategy_012408.pdf.
[61] http://www.nano.gov/NNI_EHS_research_needs.pdf.
[62] http://epa.gov/osa/nanotech.htm.

the working party. Representatives from 23 countries, the European Commission, business, labor, and environmental groups serve on the panel. Initially, the steering group for the project will focus on specific potential projects related to a goal of raising awareness about—and harmonizing approaches for—exposure measurement and mitigation in occupational settings.

- **NIOSH, ISO:** Meeting in December 2007, a project group of the ISO Technical Committee 229 voted to approve a draft report of safety and health practices in occupational settings relevant to nanotechnology. The draft report, approved for publication by the ISO TC 229 in May 2008, was based on NIOSH's interim document, "Approaches to Safe Nanotechnology," and was developed with NIOSH leadership of and participation in the project group. In 2008 and 2009 NIOSH will continue its support of international standards development activities.
- **NIOSH, World Health Organization (WHO):** In December 2007, NIOSH participated in a meeting in Helsinki, Finland, of the World Health Organization's (WHO) Global Network of Collaborating Centers in Occupational Health, focusing on nanotechnology. NIOSH staff provided input on the challenges that engineered nanoparticles pose for occupational safety and health. The objective of the meeting was to determine how the WHO collaboration can develop and support research and cooperation in preventing exposure to potentially hazardous engineered nanoparticles. NIOSH currently is collaborating on five communication and networking projects with various WHO centers.
- **NIST, European Commission (EC):** NIST has signed a collaborative agreement with the European Commission Joint Research Centre's Institute for Reference Materials and Measurements. The goal of this agreement is to enhance trade between the United States and the nations of the European Union while helping ensure the safety and quality of goods sold in both markets. The pact will advance the development and availability of international measurement standards in the fields of chemistry, life sciences, and emerging technologies. A future meeting will address new measurement methods, technologies and standards for biofuels, multiplex biological measurements, and the health and environmental effects of engineered nanomaterials.
- **USDA/CSREES, Canada:** USDA/CREES is planning to hold in 2009 a joint nanotechnology grantees' meeting with the Advanced Food and Materials Network (AFMNet) of Canada. The agency is seeking an opportunity to hold this meeting in conjunction with a user workshop held at one of the NNI nanotechnology centers, or with a nanobiotechnology conference.
- **USDA/CSREES, Food Industry:** CSREES is organizing a food industry summit on nanotechnology to discuss the critical gaps for future foods and its impacts on consumer health, and to explore principles and appropriate models of public-private partnership to effectively advance nanotechnology for better and safer foods.

External Reviews of the NNI

Public Law 108-153 calls for periodic external reviews of the NNI by the National Research Council (NRC) of the National Academies and by the National Nanotechnology Advisory Panel.

Review by the National Research Council of the National Academies

The last comprehensive National Academies review, *A Matter of Size: Triennial Review of the National Nanotechnology Initiative*,[63] was released in December 2006. The NRC findings and recommendations are discussed in detail in the NNI Supplement to the President's 2008 Budget.[64] The following sections quote the recommendations of the NRC review panel and then summarize how the NNI participating agencies are now responding to the recommendations:

- *The federal government [should] sustain [nanoscale science and technology] 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 investments in U.S. physical sciences and engineering research.* [pp. 7–8]
  - As documented in this report, the NNI investment is being sustained, and in a manner that reflects the goals set out in the updated December 2007 NNI Strategic Plan. Increased investments in U.S. physical sciences and engineering research that are complementary to the NNI investments have been proposed under the President's American Competitiveness Initiative.
- *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…* [p. 8]
  - The President's Council of Advisors on Science and Technology (PCAST) is currently designated as the National Nanotechnology Advisory Panel (NNAP) called for under PL 108-153. The Administration continues to view the PCAST as the most appropriate independent advisory panel to serve in this role, given the breadth of the nanoscale science and technology endeavor in terms of the number of fields of science and engineering that it encompasses, the wide variety of industries that it impacts, and the need for special emphasis on commercialization and technology transfer activities within the NNI in order to realize the promise of nanotechnology. Specific technical expertise in nanotechnology is provided to PCAST/NNAP by a Nanotechnology Technical Advisory Group organized on behalf of NNAP by the staff of the Office of Science and Technology Policy. Members of the NSET Subcommittee provide additional specific technical expertise to PCAST.
- *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.* [p. 9]
  - The members of the NSET Subcommittee and the NNCO staff are working with the Office of Management and Budget on an ongoing basis to address this 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.* [pp. 9–10]
  - The NSET Subcommittee is supporting the OECD Committee for Scientific and Technological Policy (CSTP) on a number of projects addressing broader issues related to nanotechnology, such

[63] http://books.nap.edu/catalog.php?record_id=11752.
[64] http://www.nano.gov/NNI_08Budget.pdf, pp. 27–28.

as economic impact, education and training, and public communication. One of the specific tasks that CSTP is addressing is the development of metrics for assessing economic impacts of nanotechnology. In addition to financial support from the NSET Subcommittee, staff support is being provided by several NSET Subcommittee member agencies, particularly the Department of State and the Department of Commerce.

- *Research on the environmental, health, and safety effects of nanotechnology [should] be expanded.* [p. 11]
  - Sharply increased NNI investments in EHS research are documented elsewhere in this report.
- *The NSET Subcommittee [should] create a working group on education and the workforce that engages the Department of Education and the Department of Labor as active participants. [p. 40]*
  - As recommended by the 2005 PCAST/NNAP review of the NNI, the NSET Subcommittee has engaged these two departments; the creation of a formal working group is under consideration.

The next National Academies review of the NNI is already underway. This study will focus on assessing the NNI *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research* released by the NSET Subcommittee in February 2008. Members of the NSET Subcommittee and the NNCO staff are providing information in support of this new study as requested.

Review by President's Council of Advisors on Science and Technology, Designated as the National Nanotechnology Advisory Panel

The most recent external review of the NNI was released by the PCAST/NNAP in April of 2008.[65] The NNAP findings are summarized in the report's executive summary as follows:

- *The NNAP finds that the United States remains a leader in nanotechnology based on various metrics.*
- *The NNAP commends and encourages the ongoing NNI investment in infrastructure and instrumentation.*
- *Advances in nanotechnology are embodied in a growing number of applications and products in various industries.*
- *The NNAP views the approach for addressing EHS research under the NNI as sound.*
- *In consultation with the President's Council on Bioethics, the panel concluded that at present, nanotechnology does not raise ethical concerns that are unique to the field.*
- *Overall, the members of the NNAP feel that the NNI continues to be a highly successful model for an interagency program; it is well organized and well managed.*

The NNAP recommendations are summarized as follows in the report's executive summary:

- *Infrastructure, management, and coordination. The NNAP feels that the substantial infrastructure of multidisciplinary centers, user facilities, along with instrumentation, equipment, and technical expertise, is vital to continued U.S. competitiveness in nanotechnology and should be maintained. Whereas the NNAP finds the coordination and management among the NNI participating agencies to be generally strong, intra-agency coordination should be improved, especially in large, segmented agencies. The NNI member agencies should continue to support international coordination through effective international forums, such as the Organisation for Economic Co-operation and Development (OECD). Such efforts will aid in the development of information related to health and safety, as well as addressing economic barriers and*

[65] http://ostp.gov/galleries/PCAST/PCAST_NNAP_NNI_Assessment_2008.pdf.

impacts. Implementing and monitoring this recommendation should lead to more effective use of agency resources.

- *Standards development. Nanotechnology standards are necessary for activities ranging from research and development to commerce and regulation. Federal agencies should continue to engage in national and international standards development activities. The NNI should maintain a strong U.S. representation in international forums and seek to avoid duplicative standards development work. Where appropriate, NIST and other NNI agencies should develop reference materials, test methods, and other standards that provide broad support for industry production of safe nanotechnology-based products.*
- *Technology transfer and commercialization. The NNI should continue to fund world-class research to promote technology transfer. Strong research programs produce top-notch nanoscale scientists, engineers, and entrepreneurs, who graduate with knowledge, skills, and innovative ideas. Such programs also have the potential to attract more U.S. students to related fields. NNI-funded centers should be structured to spur partnering with industry, which enhances technology transfer. The NNI should seek means to assess more accurately nanotechnology-related innovation and commercialization of NNI research results. These efforts should be coordinated with those of the OECD to assess economic impact of nanotechnology internationally.*
- *Environmental, health, and safety implications. The NNAP feels that the NNI has made considerable progress since its last review in the level and coordination of EHS research for nanomaterials. Such efforts should be continued and should be coordinated with those taking place in industry and with programs funded by other governments to avoid gaps and unnecessary duplication of work. Moreover, EHS research should be coordinated with, not segregated from, applications research to promote risk and benefit being considered together. This is particularly important when development and risk assessment research are taking place in parallel, as they are for nanotechnology today. The NNI should take steps to make widely available nonproprietary information about the properties of nanomaterials and methods for risk/benefit analysis.*
- *Societal and ethical implications. Research on the societal and ethical aspects of nanotechnology should be integrated with technical R&D and take place in the context of broader societal and ethical scholarship. The NNAP feels that this approach will broaden the range of perspectives and increase exchange of views on topics that affect society at large.*
- *Communication and outreach. The NNAP is concerned that public opinion is susceptible to hype and exaggerated statements—both positive and negative. The NNI should be a trusted source of information about nanotechnology that is accessible to a range of stakeholders, including the public. The NNI should expand outreach and communication activities by the NNCO and the Nanotechnology Public Engagement and Communications Working Group and by coordinating existing agency communication efforts. To enhance effectiveness, the information should be developed with broad input and through processes that incorporate two-way communication with the intended audiences.*

The NSET Subcommittee is taking the findings and recommendations of the PCAST/NNAP into consideration as it formulates its plans for the future.

APPENDIX A. GLOSSARY

AF&PA	American Forest & Paper Association
Agencies	Departments, agencies, and commissions within the Executive Branch of U.S. Federal Government
ANSI	American National Standards Institute
ARO	Army Research Office (DOD)
BIS	Bureau of Industry and Security (DOC)
CBAN	Cooperative Board for Advancing Nanotechnology
CNST	Center for Nanoscale Science and Technology (DOC/NIST)
CNT	Carbon nanotube
CPSC	Consumer Product Safety Commission
CSREES	Cooperative State Research, Education, and Extension Service (USDA)
CT	Committee on Technology of the NSTC
DHS	Department of Homeland Security
DHHS	Department of Health and Human Services
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOEd	Department of Education
DOJ	Department of Justice
DOL	Department of Labor
DOS	Department of State
DOT	Department of Transportation
DOTreas	Department of the Treasury
DTRA	Defense Threat Reduction Agency (DOD)
DURIP	Defense University Research Instrumentation Program (DOD)
EERE	[Office of] Energy Efficiency and Renewable Energy (DOE)
EHS	Environmental, health, and safety
ELSI	Ethical, legal, and other societal implications
EPA	Environmental Protection Agency
EPO	European Patent Office

FDA	Food and Drug Administration (DHHS)
FHWA	Federal Highway Administration (DOT)
JPO	Japan Patent Office
FR	Flame-retardant (materials)
FS	[U.S.] Forest Service (USDA)
GIN	Global Issues in Nanotechnology (NSET Subcommittee working group)
IARPA	Intelligence Advanced Research Projects Activity
ISO	International Organization for Standardization
ITC	International Trade Commission
JSC	Johnson Space Center (NASA)
MANTECH	Manufacturing Technology (DOD)
MEMS	Microelectromechanical systems
MOU	Memorandum of Understanding
MRSEC	Materials Research Science and Engineering Center (NSF)
MURI	Multidisciplinary Research Program of the University Research Initiative (DOD)
MWCNT	Multi-walled carbon nanotube
NASA	National Aeronautics and Space Administration
NCI	National Cancer Institute (DHHS/NIH)
NCL	Nanotechnology Characterization Laboratory (DHHS/NIH/NCI)
NCLT	National Center for Learning and Teaching in Nanoscale Science and Engineering (NSF)
NCN	Network for Computational Nanotechnology (NSF)
NCTR	National Center for Toxicological Research (DHHS/FDA)
NEHI	Nanotechnology Environmental and Health Implications Working Group of the NSET Subcommittee
NEMS	Nanoelectromechanical systems
NHGRI	National Human Genome Research Institute (DHHS/NIH)
NHLBI	National Heart, Lung, and Blood Institute (DHHS/NIH)
NIBIB	National Institute of Biomedical Imaging and Bioengineering (DHHS/NIH)
NIEHS	National Institute of Environmental Health Sciences (DHHS/NIH)
NIH	National Institutes of Health (DHHS)
NILI	Nanotechnology Innovation and Liaison with Industry Working Group of the NSET Subcommittee
NIMH	National Institute of Mental Health (DHHS/NIH)

NIOSH	National Institute for Occupational Safety and Health (DHHS/Centers for Disease Control and Prevention)
NISE	Nanoscale Informal Science Education (NSF-supported network)
NIST	National Institute of Standards and Technology (DOC)
NNAP	National Nanotechnology Advisory Panel
NNCO	National Nanotechnology Coordination Office
NNI	National Nanotechnology Initiative
NNIN	National Nanotechnology Infrastructure Network (NSF program)
NNN	National Nanomanufacturing Network
NRC	Nuclear Regulatory Commission
NRI	Nanoelectronics Research Initiative (industry-led private-public partnership)
NSEC	Nanoscale Science and Engineering Centers (NSF program)
NSET	Nanoscale Science, Engineering, and Technology Subcommittee of the NSTC
NSF	National Science Foundation
NSP	Nanotechnology Standards Panel (ANSI)
NSRC	Nanoscale Science Research Centers (DOE program)
NSTC	National Science and Technology Council
NTF	Nanotechnology Task Force (FDA)
NTP	National Toxicology Program (DHHS)
OECD	Organisation for Economic Co-operation and Development
OMB	Office of Management and Budget (Executive Office of the President)
OSTP	Office of Science and Technology Policy (Executive Office of the President)
PCA	Program Component Area
PCAST	President's Council of Advisors on Science and Technology
RFA	Request for applications (NIH program solicitation)
SBIR	Small Business Innovation Research Program
SC	Office of Science (DOE)
TAG	Technical Advisory Group (ANSI/ISO)
TSCA	Toxic Substances Control Act
STTR	Small Business Technology Transfer Program
USGS	U.S. Geological Survey (Department of the Interior)
USPTO	U.S. Patent and Trademark Office (DOC)
USDA	U.S. Department of Agriculture

WHO	World Health Organization
WPMN-CC	Working Party on Manufactured Nanomaterials under the Chemicals Committee (OECD)
WPN-CSTP	Working Party on Nanotechnology under the Committee for Scientific and Technological Policy (OECD)

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