DRAFT

National Nanotechnology Initiative Strategic Plan 2010

This draft of the National Nanotechnology Initiative was posted at strategy.nano.gov for public comment on November 1, 2010. Public comments (4,000 characters or less) are invited until 11:59 p.m. EST on November 30, 2010, at the Strategy Portal as a registered community member or via email to nnistrategy@ostp.gov. All comments may be made available for public inspection; do not include in your comments information of a confidential nature.

About the National Science and Technology Council

The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of the NSTC is establishing clear national goals for Federal science and technology investments. The NSTC prepares research and development strategies that are coordinated across Federal agencies to form investment packages aimed at accomplishing multiple national goals. The work of the NSTC is organized under four committees: Science; Technology; Environment, Natural Resources, and Sustainability; and Homeland and National Security. Each of these committees oversees subcommittees and working groups focused on different aspects of science and technology. More information is available at http://www.whitehouse.gov/administration/eop/ostp/nstc.

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The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976. OSTP's responsibilities include advising the President in policy formulation and budget development on questions in which science and technology are important elements; articulating the President's science and technology policy and programs; and fostering strong partnerships among Federal, state, and local governments, and the scientific communities in industry and academia. The Director of OSTP is Assistant to the President for Science and Technology and also manages the NSTC. More information is available at http://www.ostp.gov.

About the Nanoscale Science, Engineering, and Technology Subcommittee

The Nanoscale Science, Engineering, and Technology (NSET) Subcommittee is the interagency body responsible for coordinating, planning, implementing, and reviewing the National Nanotechnology Initiative (NNI). The NSET is a subcommittee of the Committee on Technology of the National Science and Technology Council. The National Nanotechnology Coordination Office (NNCO) provides technical and administrative support to the NSET Subcommittee and its working groups in the preparation of multiagency planning, budget, and assessment documents related to the NNI, including this strategy document. More information is available at http://www.nano.gov.

About this Document

This document is the strategic plan for the NNI. It describes the NNI vision and goals and the strategies by which these goals are to be achieved. The plan includes a description of the NNI investment strategy and the program component areas called for by the 21st Century Research and Development Act of 2003, and also identifies specific objectives toward collectively achieving the NNI vision. This plan updates and replaces the NNI Strategic Plan of December 2007.

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NATIONAL NANOTECHNOLOGY INITIATIVE

Strategic Plan

December, 2010

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

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The NNI

The National Nanotechnology Initiative (NNI) is the interagency program for coordinating research and development and enhancing communication and collaborative activities in nanoscale science, engineering, and technology. This chapter describes the NNI, including the vision and goals that frame the NNI, the categorization of Federal activities in nanotechnology, and the participating NNI agencies.

Introduction

Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. The fertile intersection of disciplines at the core of nanotechnology innovation—cutting across physical, life, and social sciences and engineering—has revealed the potential of nanomaterials and nanoscale engineering to collect and store energy, reinforce materials, sense contaminants, enable life-saving drugs, and shrink and accelerate computational devices in both incremental and paradigm-shifting ways. Further, nanotechnology has enabled development of entirely new materials and devices that could be exploited in each of these and countless other applications.

The United States has set the pace for nanotechnology innovation world-wide with the **National Nanotechnology Initiative (NNI)**. Launched in 2001 with eight agencies, the NNI today consists of the individual and cooperative nanotechnology-related activities of 25 Federal agencies with a range of research and regulatory roles and responsibilities. Fifteen of the participating agencies have R&D budgets that relate to nanotechnology, with the reported NNI budget representing the collective sum of these investments. Funding support of nanotechnology R&D stems directly from NNI member agencies, not the NNI. As an interagency effort, the NNI informs and influences the Federal budget and planning processes through its member agencies and through the National Science and Technology Council.

Coordinated under the Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the National Science and Technology Council's Committee on Technology, the NNI provides a framework for a comprehensive nanotechnology R&D program by establishing shared goals, priorities, and strategies complementing agency-specific missions and activities and providing avenues for individual agencies to leverage the resources of all participating agencies. Further, the NNI provides a central interface with academia and industry as well as regional/state organizations and international counterparts in the process of innovating nanotechnology. To these ends, the National Nanotechnology Coordination Office (NNCO) provides technical and administrative support for the NSET Subcommittee, serves as a central point of contact for Federal nanotechnology R&D activities, and provides public outreach on behalf of the NNI.

The ten-year history of U.S. leadership in fundamental nanotechnology research and development under the NNI has established a thriving nanotechnology R&D environment, laid the crucial groundwork for developing commercial applications and scaling up production, and created demand for many new nanotechnology and manufacturing jobs in the near-term. The NNI has dramatically expanded scientific understanding of nanoscale phenomena and enabled engineering of applications through an extensive, unparalleled infrastructure of R&D centers, networks, and user facilities. The Federal investments in nanotechnology research and development over the past decade have positioned the United States to address key national priorities, bring new expertise to bear on important scientific and social problems, strengthen the "social contract" between science and society, and inspire a growing number of students to pursue careers in science, technology, engineering, and mathematics. Commercialization resulting from NNI-supported research is mounting.

While the progress of nanotechnology innovations to date has been significant, numerous challenges still exist, and the tremendous potential anticipated from nanoscale research and development (R&D) is still

far from full realization. Exploiting the full value of nanotechnology innovation depends on sustained fundamental R&D and on focused commercialization efforts. Barriers need to be lowered and pathways streamlined to transfer emerging nanotechnologies into economically viable applications. Researchers, educators, and technicians with new cross-cutting skills are required. Furthermore, at every step there must be a commitment to developing nanotechnology responsibly, with balanced and transparent consideration of the benefits and risks associated with particular nanomaterials in specific applications. For these reasons, broad-based coordination and integration of development efforts across government agencies, disciplines, industries, and even countries remain critical to achieving the full economic and societal benefits proven in concept or still promised by nanotechnology.

The **National Nanotechnology Initiative Strategic Plan** is the framework that underpins the nanotechnology work of the NNI member agencies. It aims to ensure that advancements in and applications of nanotechnology R&D to agency missions and the broader national interest continue unabated in this still-young area of research and development. Its purpose is to facilitate achievement of the NNI vision by laying out guidance for agency leaders, program managers, and the research community regarding planning and implementation of nanotechnology R&D investments and activities.

The NSET Subcommittee solicited multiple streams of input to inform the development of this 2010 revised NNI Strategic Plan. Independent reviews of the NNI by the President's Council of Advisors on Science and Technology and the National Research Council of the National Academies—strongly supportive of the NNI overall—have made specific recommendations for improving the NNI.[1] Additional input has come from a Strategic Planning Stakeholders Workshop sponsored by the NSET Subcommittee during July 13–14, 2010, as well as from detailed responses to a Request for Information published via the Federal Register and from online dialog in the NNI Strategy Portal.[2]

Thus informed by feedback and recommendations from a broad array of stakeholders, this strategic plan represents the consensus of the participating agencies as to the high-level goals and priorities of the National Nanotechnology Initiative and specific objectives for at least the next three years. The strategic plan provides the framework within which each agency will carry out its own mission-related nanotechnology programs and that will sustain coordination of interagency activities. It describes the four overarching goals of the NNI, the major Program Component Areas established in 2004 to broadly track the categories of investments needed to ensure the success of the initiative, and the near-term objectives that will be the concrete steps taken toward collectively achieving the NNI vision and goals. Finally, the plan describes collaborative interagency activities, including three *Nanotechnology Signature Initiatives* that are a new model of specifically targeted and closely coordinated interagency, cross-sector collaboration designed to accelerate innovation in areas of national priority. The first three signature initiatives are focused on renewable energy, sustainable manufacturing, and next-generation electronics.

The 21st Century Nanotechnology Research and Development Act of 2003 calls for the NNI Strategic Plan to be updated triennially; the plan presented here updates and replaces the December 2007 plan.

[1] See Appendix A for details on external reviews and assessments of the NNI.
[2] Details on the workshop, Federal Register notice, and NNI Strategy Portal are available in Appendix A.

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.

Vision and Goals

The vision of the National Nanotechnology Initiative (NNI) is ***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 National Nanotechnology Initiative expedites the discovery, development, and deployment of nanoscale science, engineering, and technology to serve the public good, through a program of coordinated research and development aligned with the missions of the participating agencies. In order to realize the NNI vision, the participating agencies are working collectively toward the following four goals:

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

The NNI ensures United States leadership in nanotechnology research and development by stimulating discovery and innovation. This program expands the boundaries of knowledge and develops technologies through a comprehensive program of research and development. The NNI agencies invest at the frontiers and intersections of many disciplines, including biology, chemistry, engineering, materials science, and physics. The interest in nanotechnology arises from its potential to significantly impact numerous fields, including aerospace, agriculture, energy, the environment, healthcare, information technology, homeland security, national defense, and transportation systems.

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

Nanotechnology contributes to United States competitiveness and national security by improving existing products and processes and by creating new ones. The NNI implements strategies that maximize the economic benefits of its investments in nanotechnology, based on understanding the fundamental science and responsibly translating this knowledge into practical applications.

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

A skilled science and engineering workforce, leading-edge instrumentation, and state-of-the-art facilities are essential to advancing nanotechnology research and development. Educational programs and resources are required to produce the next generation of nanotechnologists, that is, the researchers, inventors, engineers, and technicians who drive discovery, innovation, industry, and manufacturing.

Goal 4: Support responsible development of nanotechnology.

The NNI aims to maximize the benefits of nanotechnology and at the same time to develop an understanding of potential risks and to develop the means to manage them. Specifically, the NNI pursues a program of research, education, and communication focused on environmental, health, safety, and broader societal dimensions of nanotechnology development.

Program Component Areas

Program component areas (PCAs) are major subject areas under which are grouped related nanotechnology R&D projects and activities. They provide an organizational framework for categorizing the activities of the NNI. Investment and progress in these areas is critical to achieving the NNI's goals and to realizing its vision. The investment related to each PCA is reported in the annual NNI supplement to the President's Budget.[3] The eight PCAs are described in Table 1. Agency projects and activities in one or more PCAs are critical to progress toward realizing each goal.

Table 1. Program Component Areas

No.	PCA Title	Description
1	*Fundamental Nanoscale Phenomena and Processes*	Discovery and development of fundamental knowledge pertaining to new phenomena in the physical, biological, and engineering sciences that occur at the nanoscale. Elucidation of scientific and engineering principles related to nanoscale structures, processes, and mechanisms.
2	*Nanomaterials*	Research aimed at the discovery of novel nanoscale and nanostructured materials and at a comprehensive understanding of the properties of nanomaterials (ranging across length scales, and including interface interactions). R&D leading to the ability to design and synthesize, in a controlled manner, nanostructured materials with targeted properties.
3	*Nanoscale Devices and Systems*	R&D that applies the principles of nanoscale science and engineering to create novel, or to improve existing, devices and systems. Includes the incorporation of nanoscale or nanostructured materials to achieve improved performance or new functionality. To meet this definition, the enabling science and technology must be at the nanoscale, but the systems and devices themselves are not restricted to that size.
4	*Instrumentation Research, Metrology, and Standards for Nanotechnology*	R&D pertaining to the tools needed to advance nanotechnology research and commercialization, including next-generation instrumentation for characterization, measurement, synthesis, and design of materials, structures, devices, and systems. Also includes R&D and other activities related to development of standards, including standards for nomenclature, materials characterization and testing, and manufacture.
5	*Nanomanufacturing*	R&D aimed at enabling scaled-up, reliable, and cost-effective manufacturing of nanoscale materials, structures, devices, and systems. Includes R&D and integration of ultra-miniaturized top-down processes and increasingly complex bottom-up or self-assembly processes.
6	*Major Research Facilities and Instrumentation Acquisition*	Establishment of user facilities, acquisition of major instrumentation, and other activities that develop, support, or enhance the nation's scientific infrastructure for the conduct of nanoscale science, engineering, and technology R&D. Includes ongoing operation of user facilities and networks.
7	*Environment, Health, and Safety*	Research primarily directed at understanding the environmental, health, and safety impacts of nanotechnology development and corresponding risk assessment, risk management, and methods for risk mitigation.
8	*Education and Societal Dimensions*	Education-related activities such as development of materials for schools, undergraduate programs, technical training, and public communication, including outreach and engagement. Research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, workforce, educational, ethical, and legal implications.

[3] All annual supplements are available at http://www.nano.gov.

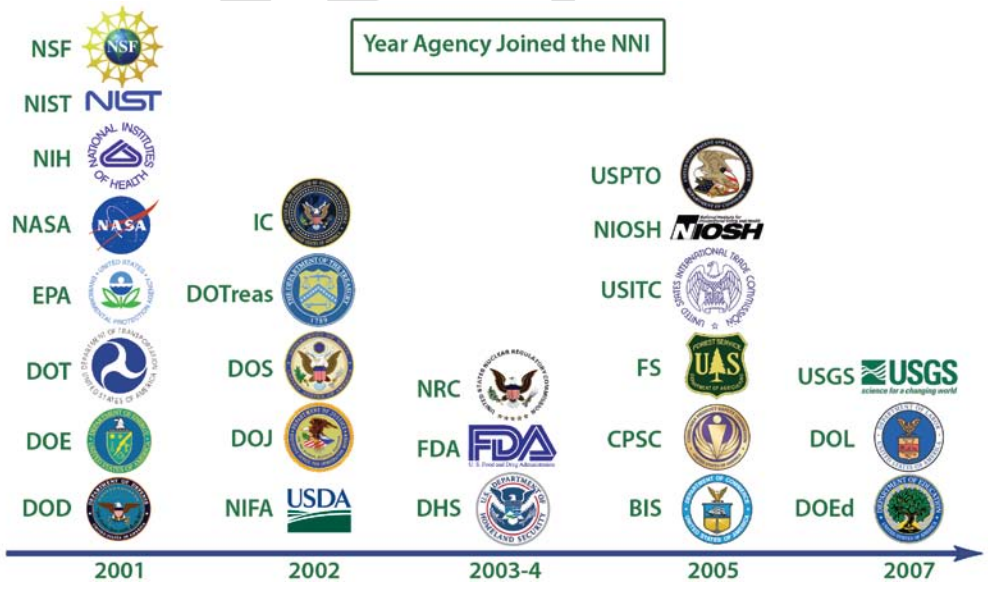
NNI Participating Agencies in 2010

Federal Agencies with Budgets Dedicated to Nanotechnology Research and Development

Consumer Product Safety Commission (CPSC)
Department of Defense (DOD)
Department of Energy (DOE)
Department of Homeland Security (DHS)
Department of Justice (DOJ)
Department of Transportation (DOT, including the Federal Highway Administration, FHWA)
Environmental Protection Agency (EPA)
Food and Drug Administration (FDA, Department of Health and Human Services)
Forest Service (FS, Department of Agriculture)
National Aeronautics and Space Administration (NASA)
National Institute for Occupational Safety and Health (NIOSH, Department of Health and Human Services)
National Institute of Food and Agriculture (NIFA, Department of Agriculture)[4]
National Institutes of Health (NIH, Department of Health and Human Services)
National Institute of Standards and Technology (NIST, Department of Commerce)
National Science Foundation (NSF)

Other Participating Agencies

Bureau of Industry and Security (BIS, Department of Commerce)
Department of Education (DOEd)
Department of Labor (DOL)
Department of State (DOS)
Department of the Treasury (DOTreas)
Intelligence Community (IC)
Nuclear Regulatory Commission (NRC)
U.S. Geological Survey (USGS, Department of the Interior)
U.S. International Trade Commission (USITC)[5]
U.S. Patent and Trademark Office (USPTO, Department of Commerce)



[4] Formerly the Cooperative State Research, Education, and Extension Services (CSREES).
[5] Observer status.

Relationship between PCAs and Agency Interests

The NNI Program Component Areas cut across the interests and activities of the participating agencies and represent areas where achieving the goals of the NNI can be expedited through interagency coordination. Table 2 shows, for each participating agency, which PCAs have the strongest relationships to the agency's mission, interests, and needs. The strength of the relationships shown may correlate with the level of that agency's investment. However, in some cases—especially for those agencies that do not have nanotechnology R&D budgets—there are nevertheless strong connections between PCAs and agency missions.

Table 2. Relationship between the PCAs and the Missions, Interests, and Needs of NNI Agencies (P = primary, S = secondary)

	1 Fundamental Nanoscale Phenomena & Processes	2 Nano-materials	3 Nanoscale Devices & Systems	4 Instrument Research, Metrology, & Standards	5 Nano-manufacturing	6 Major Research Facilities & Instrumentation Acquisition.	7 Environment, Health, & Safety	8 Education & Societal Dimensions
BIS (DOC)	S	P	P	P	S			
CPSC	S	S	P	P	S		P	S
DHS	S	S	P	P	S	S		
DOD	P	P	P	S	P	S	S	S
DOEd							S	P
DOE	P	P	S	S	S	P	S	S
DOJ			P					
DOL		S			S		P	P
DOS	S	S	S	S	S	S	P	P
DOT	P	P	P		S		S	
DOTreas		P	P					
EPA	S	P	P	S	P		P	S
FDA (HHS)	S	S	S	S	S		P	
FS (USDA)	S	P	P	S	P		S	
IC/DNI	P	P	P	S	P			
NASA	S	P	P		S	S		
NIFA (USDA)	P	P	P	S	S		P	P
NIH (HHS)	P	P	P	S	S	S	P	S
NIOSH (HHS)		S			S		P	S
NIST (DOC)	P	P	S	P	P	P	S	S
NRC		P	S					
NSF	P	P	P	S	P	P	P	P
USGS (DOI)	P			P			P	
USITC		P	P		P			
USPTO(DOC)		P	P	P	P			

Agency Interests in Nanotechnology R&D and the NNI

In August 2000, the Subcommittee on Nanoscale Science, Engineering, and Technology was constituted as part of the NSTC Committee on Technology specifically to facilitate interagency collaboration on nanoscale R&D and to provide a framework for setting Federal R&D budget priorities related to nanotechnology. The NSET Subcommittee member agencies with budgets dedicated to nanotechnology R&D continue to fund these programs because the work done so far continues to support the early assumptions about the value of this growing scientific endeavor. Moreover, the platform for communication, collaboration, and coordination provided by the NNI through the NSET Subcommittee continues to foster the engagement of all member agencies, including those with an interest, though no targeted funding, in nanotechnology. The agencies describe below their individual interests in nanotechnology R&D and the value of the NNI, as they collectively contribute by various means to the welfare of the nation and to their respective agency missions and responsibilities.

Bureau of Industry and Security, Department of Commerce (BIS/DOC)

The interagency coordination provided by the NNI enables the Bureau of Industry and Security to stay apprised of new nanotechnology advancements that may present national security challenges and may provide opportunities for companies in the national defense industrial base. Further, the NNI creates mechanisms (i.e., through regular meetings of the NSET Subcommittee) for BIS to share information about national security needs and challenges with other Federal agencies. BIS may also exercise its statutory data collection authority, as needed in support of the NNI vision. Together, these exchanges support the BIS mission to advance U.S. national security, foreign policy, and economic objectives by ensuring an effective export control and treaty compliance system and promoting continued U.S. strategic technology leadership.

Consumer Product Safety Commission (CPSC)

The NNI has engaged a number of Federal agencies in the responsible development and regulation of nanotechnology and has encouraged the Federal agencies with regulatory responsibility to be vigilant and proactive in their efforts regarding nanotechnology-enabled products. The CPSC staff believes that the Commission can meet the regulatory challenges of nanotechnology and have determined that existing regulations such as the Consumer Product Safety Act (CPSA) and the Federal Hazardous Substances Act (FHSA) are adequate to address the potential hazards associated with nanomaterial use in consumer products. The Commission will need to allocate resources and work with its Federal partners to adequately address the myriad issues and questions surrounding the implications of nanotechnology use in consumer products. The NNI plays a critical role in facilitating cooperation between the CPSC and other Federal agencies to address regulatory issues with respect to nanotechnology.

The CPSC staff is working diligently to meet the challenges involved in regulating this emerging technology. Despite relatively limited budget resources for nanotechnology, CPSC is playing an important role in developing and implementing Federal reports and activities that address the environmental, health, and safety (EHS) issues associated with the use of nanotechnology. Activities have also focused on informing researchers, manufacturers, international regulatory bodies, and the general public about the importance of responsible development of commercial nanotechnology-enabled products..

The CPSC has developed a nanotechnology team comprised of staff from various divisions and offices within CPSC with a variety of technical expertise and experience in product safety (e.g, engineering, economics, toxicology). The team advises on development of agency activities on nanotechnology and engages other regulatory agencies and the general public on issues related to nanomaterials.

In order to meet identified data needs, the CPSC staff has met with and collaborates with staff at a number of Federal agencies in areas of mutual interest where collaboration would be beneficial and support the respective missions of each agency. Federal partners include the National Institutes of Standards and

Technology, the Environmental Protection Agency, The Food and Drug Administration, and the National Institute for Occupational Safety and Health. As examples of colloborative projects, the CPSC staff has signed a memorandum of understanding (MOU) with NIST to review nanoscale flame retardants in various products and has developed an interagency agreement (IAG) with NIOSH to conduct laboratory investigations of emissions of nanomaterials from selected consumer products.

Department of Defense (DOD)

DOD leadership considers nanotechnology to have high and growing potential to contribute to the warfighting capabilities of the nation. Because of the broad and interdisciplinary nature of nanotechnology, DOD leadership views it as an enabling technology area that should receive the highest level of department attention and coordination. The vision and capability construct of Defense Research and Engineering includes nanotechnology as one of four exemplary foundational technologies, along with advanced materials, advanced electronics, and manufacturing technology. DOD Basic Research acknowledges that realizing the potential of nanotechnology is a key research objective. In particular, nanotechnology is an enabling technology for new classes of sensors (such as novel focal plane arrays and chemical/biological threat sensors), communications, and information processing systems needed for qualitative improvements in persistent surveillance. The DOD also invests in nanotechnology for advanced energetic materials, photocatalytic coatings, active microelectronic devices, structural fibers, strength- and toughness-enhancing additives, advanced processing, and a wide array of other promising applications. The DOD nanotechnology efforts are based on coordinated planning and federated execution among the military departments and agencies (e.g., the Defense Advanced Research Projects Agency and the Defense Threat Reduction Agency). Although DOD does not establish funding targets for nanotechnology specifically, its support for nanotechnology-related research and development has continued to increase through its competitive success in core research planning, technology development solicitations, and Federal programs such as Small Business Innovation Research (SBIR) and the Multidisciplinary University Research Initiative.

DOD was among the initial participating agencies in the NNI and the NSET Subcommittee. The department considers the initiative and its formal coordination fora to have been and to continue to be valuable as a means to facilitate technology planning, coordination, and communication among the Federal agencies. The meetings and workshops hosted or facilitated by the NNI participants help to identify and define options and opportunities that materially contribute to DOD planning activities and program formulation. The reviews and collegial meetings, working groups, and task forces established under the auspices of NSET are valuable means of formal and informal coordination at the Federal level and form a solid basis for exploring collaborative activities, addressing mutual or pervasive issues, and identifying areas in which interagency assistance is needed or would be productive. The DOD has continuously contributed to the NNI through participation in the above-noted activities and through numerous outreach and programmatic efforts in which nanotechnology has been a principal aspect of the program or planning. The transparency that is enabled by the NNI is viewed as symmetrically beneficial to DOD, the other agencies, and the many private-sector stakeholders in the broad arena of nanoscience, nanotechnology, and nanotechnology-enabled applications.

Department of Education (DOEd)

The Department of Education faces major challenges in a number of education-related areas, including a need for more graduates and researchers in areas of science, technology, engineering, and mathematics (STEM) education. By providing working groups, regular NSET Subcommittee meetings, and inter-agency communication channels, the NNI provides a mechanism for DoEd to better collaborate with other relevant agencies, such as the National Science Foundation, which makes substantial investments in nanotechnology-related education, and the Department of Labor, which follows trends in workforce needs.

Department of Energy (DOE)

DOE leadership views nanoscience and nanotechnology as having a vitally important role to play in solving the energy and climate change challenges faced by the nation. This broad and diverse field of research and development will likely have dramatic impact on future technologies for solar energy collection and conversion, energy storage, alternative fuels, and energy efficiency, to name just a few. DOE has participated in the NNI since its inception in 2001 and maintains a strong commitment to the initiative, which has served as an effective and valuable way of spotlighting needs and targeting resources in this critical emerging area of science and technology. The NNI continues to provide a focus for overall investment in physical sciences, a crucial locus for interagency communication and collaboration, and an impetus for coordinated planning. The research and infrastructure successes spurred by the NNI have made the United States the world leader in this area, with significant national benefit.

DOE funding spans all eight program component areas of the NNI, with the majority falling into three categories: fundamental phenomena and processes (PCA 1), nanomaterials (PCA 2), and major research facilities and instrumentation acquisition (PCA 6). In the latter category, the DOE investment is significantly larger than that of any other agency, due primarily to the planning, construction, and operation of five Nanoscale Science Research Centers (NSRCs) located at DOE laboratories. The NSRCs operate as user facilities, with access based on submission of proposals that are reviewed by independent evaluation boards, and at no cost for nonproprietary work. The NSRCs support synthesis, processing, fabrication, and analysis at the nanoscale and are designed to be state-of-the-art user centers for interdisciplinary nanoscale research, serving as an integral part of DOE's comprehensive nanoscience program that encompasses new science, new tools, and new computing capabilities.

Department of Homeland Security (DHS)

DHS interests in nanoscience are primarily focused on the application of nanoscale materials and devices that provide enhancements in component technology performance for homeland security applications. The applications for the efforts described below are in threat detection for enhanced security for aviation, mass transit, and first responders:

- *Materials toolbox*: These efforts are focused on the development of materials systems that allow systematic control of chemical and structural features from molecular scales (functional groups) through nano- and microscales. The ability to precisely tune material properties is critical for successful development of improved active sensor surfaces and analyte collection substrates as well as development of novel sensing structures and arrays.
- *Advanced preconcentrators*: The DHS Science and Technology Directorate is currently investigating the development of high-performance preconcentrators for use in next-generation detection systems. The focus of these efforts is the development of nano- and microscale materials that enable radio-frequency and optical control of device temperature. To date, several functional prototypes have been demonstrated. Commercialization of these devices is currently being pursued.
- *Advanced sensing platforms*: Work on the development of multimodal carbon nanotube sensing platforms continues with industry partners. The emphasis of these efforts is on development of manufacturing techniques for low-cost sensor platforms.

Department of Justice/National Institute of Justice (DOJ/NIJ)

The NIJ investment in nanotechnology furthers the Department's mission through sponsoring research that provides objective, independent, evidence-based knowledge and tools to meet the challenges of crime and justice, particularly at the state and local levels. New projects are awarded on a competitive basis, and therefore, total investment may change each fiscal year. However, NIJ continues to view nanotechnology as an integral component of its research and development portfolio as applicable to criminal justice needs.

Department of State (DOS)

DOS actively participates in the NNI in order to identify and promote multilateral and bilateral scientific activities that support U.S. foreign policy objectives, protect national security interests, advance economic interests, and foster environmental protection. International scientific collaboration enhances existing U.S. research, development and innovation programs, and nanotechnology's enormous potential to address global challenges such as water, health, and energy renders it an ideal subject for international collaboration on pre-competitive and non-competitive research. DOS actively coordinates these cooperative efforts with relevant agencies and their offices, such as international science programs at the National Science Foundation, cooperation on international renewable energy centers with the Department of Energy, and Global sponsored activities of the Office of Naval Research. Through Chairmanship of the NSET Subcommittee's Global Issues in Nanotechnology (GIN) Working Group, DOS coordinates U.S. government interactions with foreign governments and multilateral institutions to foster mutually beneficial cooperation on nanoscale science and technology, to develop an international marketplace for nanotechnology products and ideas, and to establish a framework for the safe, secure and responsible use of nanotechnology. DOS also leads efforts in the Working Party on Nanotechnology (WPN) of the Organisation for Economic Co-operation and Development (OECD), the Strategic Approach to International Chemicals Management (SAICM), and other international organizations to communicate these precepts globally to key policymakers and stakeholders.

Department of Transportation (DOT)

The DOT's Federal Highway Administration (FHWA) sees great promise in the application of nanotechnology to help solve long-term highway and transportation research needs in support of DOT's strategic goals: Safety, Livable Communities, State of Good Repair, Economic Competitiveness, and Environmental Sustainability. By strategically investing in focused research areas and leveraging investments in nanoscale technology by other NNI partners and Federal agencies, industry, and academia, FHWA aims to accelerate the capability to provide safer, more efficient, longer-lasting highway transportation systems. Based on the findings of a March 2009 workshop of experts from academia, DOT, and other Federal agencies, FHWA's Exploratory Advanced Research Program is investing in nanoscale research to address key highway research issues in infrastructure, safety, operations, and the environment. Nanotechnology promises breakthroughs in multiple areas, offering a potential for synergy and benefits across many traditional highway research focus areas.

The development of new and innovative materials and coatings can deliver significant improvements in durability, performance, and resiliency of highway and transportation infrastructure components. Nanoscale engineering of traditional transportation infrastructure materials such as steel, concrete, asphalt, and other cementitious materials, as well as recycled forms of these materials, offers great promise. Developments in nanoscale sensors and devices may provide cost-effective opportunities to embed and employ structural health monitoring systems to continuously monitor corrosion, material degradation, and performance of structures and pavements under service loads and conditions; In addition, these developments might provide multifunctional properties to traditional infrastructure materials, such as the ability to generate or transmit energy. Nanoscale sensors and devices may also enable a cost-effective infrastructure that communicates with vehicle-based systems to assist drivers with tasks such as maintaining lane position, avoiding collisions at intersections, and modifying or coordinating travel behavior to mitigate congestion or adverse environmental impacts. Other **e**nvironmental applications include sensors to monitor mobile source pollutants and air, water, and soil quality.

FHWA's long-term strategy is to continue targeted investment in select areas while building an appreciation for highway research needs with NNI partners and the broader nanoscale research community in order to augment longstanding partnerships and make significant progress toward improving the nation's highway and transportation systems.

Department of Treasury (DOTreas)

The Department of the Treasury works through the NSET Subcommittee to help the National Nanotechnology Initiative achieve its vision congruent with the mission of the Department: to serve the American people and strengthen national security by managing the U.S. Government's finances effectively; to promote economic growth and stability; and to ensure the safety, soundness, and security of U.S. and international financial systems. Treasury monitors those aspects of developing nanotechnology that could most effectively assist the execution of its role as the steward of the U.S. economic and financial systems, and as an influential participant in the global economy. The Treasury Department seeks to assess and utilize nanotechnology in the effective discharge of its responsibilities, including advising the President on economic and financial issues, encouraging sustainable economic growth, and fostering improved governance in financial institutions. It seeks to harness those aspects of nanotechnology R&D that will allow it to better operate and maintain systems that are critical to the nation's financial infrastructure, such as the production of coin and currency, the disbursement of payments to the American public, revenue collection, and the borrowing of funds necessary to run the Federal Government. Through the NSET Subcommittee, the Department works with other Federal agencies, foreign governments, and international financial institutions to encourage global economic growth, raise standards of living, and, to the extent possible, predict and prevent economic and financial crises. The Department endeavors to capture those developments in nanoscale science and engineering that are changing its domestic and international milieu, particularly those impacting its critical and far-reaching function in enhancing national security by implementing economic sanctions against foreign threats to the U.S., identifying and targeting the financial support networks of national security threats, improving the safeguards of our financial systems, and creating new economic and job opportunities to promote ever greater economic growth and stability at home and abroad.

Environmental Protection Agency (EPA)

The Environmental Protection Agency has a dual interest in nanotechnology for the protection of human health and the environment. First, EPA is interested in understanding the potential implications of engineered nanomaterials, including understanding how nanomaterials can be designed and used in ways that minimize any adverse public health or environmental impacts. Second, the Agency is interested in the potential of nanotechnology to improve the environment, including its use for environmental sensing, remediation, and "green" processing applications for conventional contaminants. Both interests have foundations in the theme of achieving sustainability in use of nanotechnology.

Potentially, nanotechnology offers transformational capabilities for a vast array of products and processes, including those that enhance environmental quality and sustainability. To help nanotechnology obtain maximum societal benefits and minimize its potential environmental impacts, EPA works with its Federal partners within the NSET Subcommittee to ensure research gaps are covered, critical issues are addressed, and information is communicated to all interested stakeholders.

Food and Drug Administration (FDA)

Nanostructured materials often have chemical, physical, or biological properties that are different from those of conventional materials. Such differences may include altered magnetic, electrical, or optical properties, structural integrity, and chemical or biological activity. Because of researchers' ability to engineer such properties, nanomaterials have great potential for use in a vast array of products, including FDA-regulated products. Also, because of some of their special properties, nanomaterials may pose different or additional issues for toxicologic, safety, and effectiveness assessments. As such, there is a growing need for scientific information and tools to help better predict or detect the potential impact of nanomaterials on human and animal health.

FDA nanotechnology investments in prior and future years are focused on enabling the agency to characterize nanotechnology-based products, develop models for safety and effectiveness assessment, and

study the behavior of nanomaterials in biological systems and their effects on human health. These investments support FDA's mission to protect and promote public health and help ensure the responsible development of nanotechnology.

FDA also continues to foster and develop collaborative relationships with other Federal agencies through participation in the NNI and the NSET Subcommittee, as well as with sister regulatory agencies, international organizations, healthcare professionals, industry, consumers, and other stakeholders. These collaborations allow information to be exchanged efficiently and serve to identify research needs related to the use of nanomaterials in FDA-regulated products. Although FDA activities are relevant to all four NNI goals, FDA efforts are primarily focused on Goal 4, to facilitate responsible development of nanotechnology, in three FDA priority areas: (1) building laboratory and product testing capacity, (2) establishing scientific staff development and training, and (3) engaging in collaborative and interdisciplinary research to address product characterization and safety.

Forest Service, U.S. Department of Agriculture (FS/USDA)

Nanotechnology has enormous promise to bring about fundamental changes and significant benefit to our nation's use of renewable resources. For example, cellulose nanofibers and cellulose nanocrystals derived from trees: (1) are renewable; (2) are produced in trees via photosynthesis from solar energy, atmospheric carbon dioxide, and water; (3) store carbon; and (4) depending upon how long cellulose-based products remain in service, are carbon negative or carbon neutral. These cellulose nanomaterials have strength properties greater than Kevlar®, have piezoelectric properties equivalent to quartz, and can be manipulated to produce photonic structures. The USDA Forest Service's Forest Products Laboratory, through collaborations with Purdue University and others, has been conducting research in the characterization of cellulose nanocrystals, predictive modeling of cellulose nanocrystals, surface modification of cellulose nanocrystals, and sensor development using cellulose nanocrystals. Current global research directions in cellulose nanomaterials indicate that this material could be used for a variety of new and improved product applications such as lighter and stronger paper and paperboard products, lighter and stronger building materials, wood products with improved durability, barrier coatings, body armor, automobile and airplane composite panels, electronics, biomedical applications, and replacement of petrochemicals in plastics and composites. The U.S. forest products industry, the major supplier and a user of cellulose nanomaterials, through the American Forest & Paper Association Agenda 2020 Technology Alliance has signed a memorandum of understanding with the NSET Subcommittee to form a Cooperative Board for Advancing Nanotechnology (CBAN).

By participating in the NNI and representation on the NSET Subcommittee, USDA Forest Service R&D has begun partnering with other Federal entities (e.g., NIST, NSF, DOE, DOD), industry, and academia to develop the precompetitive science and technology critical to the economic and sustainable production and use of new high-value, nanotechnology-enabled forest-based products. Participation in the NNI and the NSET Subcommittee has helped create a favorable environment for increased Forest Service investment in nanotechnology research and development. Forest Service nanotechnology research has broadly contributed to the NNI program component areas, with primary emphasis on fundamental nanoscale phenomena and processes (PCA 1), nanomaterials (PCA 2), nanoscale devices and systems (PCA 3), instrument research, metrology, and standards (PCA4), nanomanufacturing (PCA5), and with possible future investment in environment, health, and safety (PCA 7).

Intelligence Community/Director of National Intelligence (IC/DNI)

There are several agencies within the intelligence community that conduct nanotechnology research and development. The National Reconnaissance Office has an R&D program that focuses on nanoelectronics, nanomaterials, and energy generation and storage using nanotechnologies.

In nanoelectronics, both analog and digital, the emphasis is on ultralow power for terrestrial data centers and radiation-hardened ultralow power for satellites. Carbon-based nanoelectronics is compatible with

todays microelectronics and the foundries that produce them. A major focus going forward will be on ultradense, ultralow-power nonvolatile memory for saving power in data centers and satellites; replacement for today's silicon logic, and advanced linear analog nanoelectronics for next-generation communications and radar systems. These nanoelectronics will transform today's systems into advanced capabilities that will solve tomorrow's intelligence community challenges.

Nanomaterials, both carbon-based sheets and threads, will be used to develop advanced ultralight, ultrastrong composites for satellites, unmanned aircraft, and advanced body armor. Carbon-based threads will also be used to develop novel ultralightweight cables and wires for satellites, aircraft, and data centers. These carbon-based cables will reduce weight by as much as 80% and deliver more data signals and power than conventional copper wires and cables.

Nanotechnologies are being applied to solar cells to achieve 35% near-term efficiency and develop 40% to 47% efficiencies in the mid-term for use in space. With the application of 10 to 1000 sunlight concentration, 52 to 61% efficiency can be achieved for terrestrial use, as defined by current research. Carbon-based nanomaterials are also being developed for advanced lithium ion batteries with 3–5 times more power, more rapid rechargeability, and much lighter weight than current lithium ion batteries.

Nanotechnology provides the intelligence community transformative and game-changing capabilities not achievable with conventional electronics, materials, or power technologies, and with greatly reduced size, weight, and power. The NNI/NSET provides an open forum where agencies can describe their nanotechnology portfolios to other agencies, making them aware of progress achieved. It also affords the opportunity to collaborate to further accelerate nanotechnology R&D, prototyping, nanomanufacturing, *in situ* and post-product metrology, and final transition to acquisition programs. These nanotechnologies will solve many challenges of the intelligence community that current technologies cannot.

National Aeronautics and Space Administration (NASA)

The three prime drivers for NASA's spacecraft research and development activities are to (1) reduce vehicle weight, (2) enhance performance, and (3) improve safety, durability, and reliability. Nanotechnology is a tool to address each of these drivers. Nanotechnology research in NASA is focused in four areas: Engineered Materials and Structures; Energy Generation, Storage, and Distribution; Electronics, Sensors, and Devices; and Propulsion. This research is conducted through a combination of in-house activities at NASA research and flight centers, competitively funded research with universities and industry, and collaborations with other agencies, universities, and industry. Through the University Research Centers Program, NASA has also funded nanotechnology research at minority-serving institutions, including the Center for Advanced Nanoscale Materials at the University of Puerto Rico and the High Performance Polymers and Composites Center at Clark Atlanta University.

NASA has been a member of the NNI since its inception in 2001 and is committed to partnering with other member agencies to identify key technical challenges in nanotechnology R&D, focus resources to address these challenges, and accelerate the development of nanotechnology breakthroughs and their translation into commercial products.

National Institute of Food and Agriculture, U.S. Department of Agriculture (NIFA/USDA)

The National Institute of Food and Agriculture of the U.S. Department of Agriculture, established by the 2008 Farm Bill, serves the nation's needs by supporting exemplary research, education, and extension to address challenges. The NIFA's mission is to lead food and agricultural sciences to help create a better future for the nation and the world. NIFA's current priority areas are (1) global food security and hunger, (2) climate change, (3) sustainable bioenergy, (4) nutrition and childhood obesity, and (5) food safety. Nanoscale science, engineering, and technology have demonstrated their relevance and great potential to enable revolutionary improvements in agriculture and food systems, including plant production and products; animal health, production, and products; food safety and quality; nutrition, health, and wellness; renewable bioenergy and biobased products, natural resources and the environment; agriculture systems

and technology; and agricultural economics and rural communities. The agency's nanotechnology programs have broadly contributed to the NNI, with primary emphasis on fundamental nanoscale phenomena and processes (PCA 1), nanomaterials (PCA 2), nanoscale devices and systems (PCA 3), environment, health, and safety (PCA 7), and education and societal dimensions (PCA 8). NIFA's SBIR program also supports innovative nanotechnology R&D throughout its broad topic areas.

NIFA was among the early participating agencies in the NSET Subcommittee and has actively participated in and contributed to NNI activities since 2002. The NNI provides a solid platform on which NIFA can effectively explore opportunties in nanoscience and nanotechnology to address critical societal challenges facing agriculture and food systems through coordination, collaboration, and leveraging resources with other Federal agencies. Scientific discoveries and technological breakthroughs inspire agricultural and food scientists to seek novel solutions. The extensive infrastructure networks developed by the NNI enhance the productivity and expand the capability of agricultural and food science research and development in academia and industry. NIFA actively contributes to and benefits from the NNI programs in identifying research gaps and opportunities through various workshops and discussions, supporting public engagement and communication, facilitating public-private partnerships through close interaction with industries, and participating and promoting international information exchanges and cooperation. NIFA also supports multiagency joint research efforts of common interest and importance as appropriate to its mission, goals, and objectives.

National Institutes of Health (NIH)

The National Institutes of Health, a part of the U.S. Department of Health and Human Services, is the primary Federal agency for conducting and supporting medical research. The NIH mission is to seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce the burdens of illness and disability. Toward this end, NIH leadership realizes that the advances in nanoscience and nanotechnology today have the potential to make valuable contributions to biology and medicine, which in turn could contribute to a new era in healthcare. The Federal agencies' R&D investments, for example, have resulted in advanced materials, tools, and nanotechnology-enabled instrumentation that can be used to study and understand biological processes in health and disease. The NIH-supported R&D efforts, in particular, are bringing about new paradigms in the detection, diagnosis, and treatment of common and rare diseases, resulting in new classes of nanotherapeutics and diagnostic biomarkers, tests, and devices.

In 2001, the NIH became a member of the NNI in support of its mission. Today, the NNI serves as a framework within which the NIH can work collaboratively with other agencies to address some of the most perplexing challenges in the development and application of nanotechnologies for biomedical applications. Through this interagency planning, coordination, and communication, scientists are addressing key challenges by:

- Understanding the manner in which nanoscale building blocks and processes integrate and assemble into larger systems and how these processes can be precisely controlled to achieve predictable outcomes
- Learning how to design nanomaterials that can seamlessly and functionally integrate with tissues of the body to perform biological functions
- Developing "top-down" and "bottom-up" engineering approaches to control properties that allow the identification, characterization, and quantification of biological molecules, chemicals, and structures for early-stage changes or progression in a disease state
- Engineering complex, theranostic-based nanoparticles and nanodevices to target therapies and diagnosis the progress of treatments
- Adopting new materials, nanotechnology-enabled tools, and analytical instruments from diverse fields of research.

The NIH continues to support the NNI by stimulating R&D in nanoscience and nanotechnology through both intramural and extramural funding activities. This investment encompasses all eight program component areas, with major financial investments in fundamental nanoscale phenomena and processes (PCA 1), nanomaterials (PCA 2), and nanoscale devices and systems (PCA 3). NIH-funded grants on this topic are listed on the NIH report website at http://report.nih.gov/index.aspx. The NIH also plays a substantative role in developing a scientific understanding of how to design nanomaterials for safe use in manufacturing and medical treatments. The National Cancer Institute (NCI), for example, formed the Nanotechnology Characterization Laboratory, which has developed a comprehensive assay portfolio for the assessment of the safety of nanoparticles used in *in vivo* applications, and the National Institute of Environmental Health Sciences and the National Toxicology Program have focused on the assessment of properties relevant to the chronic exposure of workers to nanomaterials. The NIH institutes also support large centers grants, program grants, and small businesses whose technologies or products are liscensed or currently undergoing Phase I–III clinical trials.

National Institute for Occupational Safety and Health (NIOSH)

The National Institute for Occupatiaonl Safety and Health (NIOSH) is responsible for conducting research and providing guidance to protect the health and safety of people at work. Workers are generally the first people in society to be exposed to the hazards of an emerging technology, and nanotechnology is no exception. The workplaces where nanomaterials are developed, investigated, manufactured, used, and disposed of are quite varied and span all economic sectors. To protect the health and safety of workers in all these workplaces, NIOSH has mounted a concerted R&D and public outreach effort that includes hazard identification, exposure assessment, risk characterization, and risk management.

NIOSH toxicology studies have provided better understanding of the ways in which some types of nanoparticles may enter the body and interact with the body's organ systems; however, the breadth and depth of such research efforts have been limited to a few nanoparticle types. More of the newer types of engineered nanoparticles need to be assessed for characteristics and properties relevant for predicting potential health risks. The toxicology studies will serve as a starting point to identify the priority materials for further risk assessment, exposure evaluations, and risk management practices.

NIOSH field investigators have assessed exposure to engineered nanoparticles in a limited number of workplaces, but little data exist on the full extent and magnitude of workers' exposures to broad categories of nanoparticles in workplaces that manufacture or use nanomaterials, nanostructures, and nanodevices. Continuing and even increasing this effort will allow NIOSH field investigators to expand the scope of assessment and the number and type of facilities that can be assessed.

NIOSH guidance is a first step toward controlling nanoparticles in the workplace; however, more research is needed on the efficacy and specificity of engineering and work-practice control measures. Significantly more field research is needed to develop guidance, based on evaluating possible short- and long-term health risks in nanotechnology workers, and to develop guidance for medical surveillance and prospective epidemiologic studies.

NIOSH will continue to work with the NNI and a broad range of national and internatinal partners to develop research-based information and guidance to protect workers involved with nanomaterials. The results being produced by NIOSH will continue to serve as the foundation for meeting the critical NNI research needs related to human exposure assessment, exposure mitigation, risk assessment techniques, risk management practices, and human medical surveillance and epidemiology. NIOSH has developed formal collaborations with the National Toxicology Program of the National Institute of Environmental Health Sciences, the Consumer Product Safety Commission, the Occupational Safety and Health Administration, and the Department of Defense. It has also developed productive informal interactions with additional agencies, including the Environmental Protection Agency, National Institute of Standards and Technology, the Department of Energy, and the Food and Drug Administration.

National Institute of Standards and Technology (NIST)

Advancing nanoscale measurement science, standards, and nanotechnology is an important component of NIST's mission to promote U.S. innovation and industrial competitiveness. From leading cutting-edge research to coordinating the development of standards that promote trade and enable regulation of nanotechnology-based products, NIST's nanotechnology program directly impacts priorities important to the nation's economy and well-being. The NNI-related research conducted in NIST's laboratories and user facilities develops measurements, standards, and data crucial to a wide range of industries and Federal agencies, from the development of new spectroscopic methods needed to increase efficiency in advanced photovoltaics, to the development of the reference materials and data necessary to accurately quantify and measure the presence and impact of nanomaterials in the environment. NIST further supports the U.S. nanotechnology enterprise from discovery to production through the Center for Nanoscale Science and Technology (CNST) user facility, created under the NNI as the only national nanocenter with a focus on commerce. The CNST provides industry, academia, NIST, and other government agencies with access to world-class nanoscale measurement and fabrication methods and technology. NIST also accelerates U.S. innovation in nanotechnology by funding high-risk, high-reward research through the Technology Innovation Program (TIP), including targeted investments in nanomanufacturing research.

The NNI has enabled NIST to prioritize and coordinate nanotechnology research in numerous areas, most notably in nanoelectronics, nanomanufacturing, energy, and environmental, health, and safety aspects of nanomaterials (nano-EHS). NIST is working closely with other NNI agencies in the planning and implementation of the Signature Initiatives related to nanomanufacturing and energy. Through activities of the NSET Nanotechnology Environmental & Health Implications (NEHI) Working Group, NIST has received input from a broad range of stakeholders on the critical measurement science and measurement tools—protocols, standards, instruments, models, and validated data—required for risk assessment and management of engineered nanoscale materials and nanotechnology-based products. This input has been essential to the development of NIST's nano-EHS program, including planning goals and milestones.

NIST staff members participate widely in nanotechnology-related standards development and international cooperation activities in order to promote transfer of NIST research, technology, and measurement services, and advance NNI objectives within the Department of Commerce mission. The development of nanotechnology standards and guidelines is conducted through international fora such as the International Organization for Standardization's Technical Committee 229, the ASTM International's Committee E56, or the OECD's Working Party on Manufactured Nanomaterials, supported by NIST staff in important leadership roles and coordinated with other agencies through the GIN Working Group.

National Science Foundation (NSF)

The National Science Foundation supports fundamental nanoscale science and engineering in and across all disciplines. It also advances nanotechnology innovation through a variety of translational research programs and by partnering with industry, states, and other agencies.

The NSF investment of $418 million in the NNI in 2010 is supporting over 4,500 active projects, over 30 research centers, and several infrastructure networks for device development, computation, and education. It impacts over 10,000 students and teachers. Approximately 100 small businesses were funded to perform research and product development in nanotechnology through the SBIR and Small Business Technology Transfer (STTR) programs. NSF's nanotechnology research is supported primarily through grants to individuals, teams, and centers at U.S. academic institutions. The efforts in team and center projects have been particularly fruitful because nanoscale research and education are inherently interdisciplinary pursuits, often combining elements of materials science, engineering, chemistry, physics, and biology.

Fundamental changes envisioned through nanotechnology require a long-term R&D vision. NSF sponsored the first initiative dedicated to nanoparticles in 1991, the 1997–1999 program Partnership in Nanotechnology, and produced the 1999 interagency report *Nanotechnology Research Directions: Vision*

for Nanotechnology in the Next Decade, adopted as an official National Science and Technology Council document in 2000. It is currently in the process of updating that initial 10-year vision of the long-term impacts and future opportunities for nanoscale science and engineering. NSF continues to push the frontiers of science and technology innovations through continual interaction with the nanotechnology community, new programs, and ongoing evaluation of current investments.

NSF supports the three FY 2011 NNI Signature Initiatives through core programs and new solicitations. NSF requested additional funds in 2011 for nanomanufacturing to support new concepts for high-rate synthesis and processing of nanostructures, nanostructured catalysts, nanobiotechnology methods, and methods to fabricate devices, assemble them into systems, then into larger-scale structures of relevance to industry. Environmental, health, and safety implications of nanotechnology, including development of predictive toxicity of nanomaterials, will be investigated in three dedicated multidisciplinary centers and in over 60 other smaller groups.

Nuclear Regulatory Commission (NRC)

The mission of the U.S. Nuclear Regulatory Commission is to license and regulate the nation's civilian use of byproduct, source, and special nuclear materials in order to protect public health and safety, promote the common defense and security, and protect the environment. The NRC's scope of responsibility includes regulation of commercial nuclear power plants; research, test, and training reactors; nuclear fuel cycle facilities; medical, academic, and industrial uses of radioactive materials; and transport, storage, and disposal of radioactive materials and waste. In addition, the NRC licenses the import and export of radioactive materials and works to enhance nuclear safety and security throughout the world.

As a regulatory agency, the NRC does not typically sponsor fundamental research or product development. Rather the NRC is focused in part on confirmatory research to verify the safe application of new technologies in the civilian nuclear industry. Currently the agency's focus with respect to nanotechnology is to monitor developments that might be applied within the nuclear industry to help the NRC carry out its oversight role.

The U.S. International Trade Commission (USITC)

The U.S. International Trade Commission is an observing member of the NSET Subcommittee. The USITC representative attends meetings to keep the Commission abreast of current trends and issues related to nanotechnology that may have the potential to impact international trade.

U.S. Patent and Trademark Office (USPTO)

The strength and vitality of the United States economy depends directly on effective mechanisms that protect new ideas and investments in innovation and creativity. The United States Patent and Trademark Office is at the cutting edge of the nation's technological progress and achievement as the Federal agency responsible for granting patents, registering trademarks, and providing intellectual property policy advice and guidance to the Executive Branch. Through its participation in the National Nanotechnology Initiative, and working through the NSET Subcommittee with other agencies, the USPTO has made several improvements to its processes to keep pace with the rapid advances being made in this area. Notably, the USPTO adopted the NNI definition of nanotechnology in its development of the first detailed, patent-related nanotechnology classification hierarchy of any major intellectual property office in the world. The USPTO has also used the networking and information-sharing opportunities presented by participation in the NNI to establish nanotechnology-related training opportunities for patent examiners. The USPTO has significantly contributed to the NNI by providing advice on patent and other intellectual property-related matters, as well as contributing a variety of nanotechnology-related patent data, which has been used as a benchmark to analyze nanotechnology development and to perform trend analysis of nanotechnology patenting activity in the United States and globally.

Goals and Objectives: Research & Development in the National Interest

The NNI vision is supported by the four NNI goals. All four are equally critical to the success of the NNI and are interdependent. This interconnection is specifically recognized, as appropriate, in the following sections that describe NNI objectives shared by the member agencies, organized by NNI goal. In writing these objectives, the NNI agencies have considered, and are highly appreciative of, stakeholder input (see Appendix A). They have striven to identify objectives that are specific and measurable. The targeted time frame to achieve most objectives is three to five years. For some objectives, an explicit time frame is listed. The objectives have been selected on the basis of their rewarding and extending nature. Although not all member agencies are responsible for fulfilling all objectives, the NSET Subcommittee has identified objectives that are supported by the relevant agencies and are realistic in terms of available resources, while also being far-sighted in terms of accelerating innovation and progress toward achieving the NNI goals. NNI agencies also independently continue to contribute to the achievement of all four goals through a number of their own activities, which are reported on an annual basis in the NNI Budget Supplement.[1]

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

The NNI continues to expand the boundaries of knowledge and develop technologies through comprehensive and focused R&D within the participating agencies. The overarching objective of Goal 1 is to advance nanoscience and nanotechnology through the implementation of the objectives described below. Progress in R&D will depend upon the availability of a skilled workforce, infrastructure, and tools (Goal 3) and will lay the foundation for responsible incorporation of nanotechnology into commercial products (Goals 2 and 4).

Goal 1 Objectives

1.1 Continue to substantively support R&D at the frontiers and intersections of scientific disciplines in the form of intramural and extramural programs targeting single investigators, multi-investigator and multidisciplinary research teams, and centers for focused research.

The broad NNI R&D portfolio invests at the frontiers and intersections of many disciplines, including biology, chemistry, ecology, engineering, geology, materials science, medicine, physics, and social sciences. Activities targeted toward this goal include support for fundamental research, use-inspired research, applications research, and technology development. The research efforts of the NNI agencies continue to be executed through a balanced mix of funding ranging from single-investigator grants to research centers and user facilities, each of which plays a unique and vital role in the discovery and innovation process.

1.2 Develop at least five broad interdisciplinary nanotechnology initiatives that are each supported by three or more NNI member agencies and support significant national priorities.

No single agency within the Federal Government has the mission or breadth of expertise to fully exploit the opportunities nanotechnology presents, nor execute all the requisite research. Thus, in certain key areas, it is essential to coordinate particular NNI R&D programs across multiple agencies. NNI member agencies will identify topical areas that can most benefit from close and targeted interagency interaction,

[1] Available at http://nano.gov.

or "NNI Signature Initiatives." These will be implemented through the broad range of funding mechanisms identified in Objective 1.1 and will be coordinated to foster innovation and accelerate nanotechnology development.

1.3 Identify and support goal-oriented nanoscale science and technology research aimed at national priorities informed by active engagement with academia, industry, and other stakeholders.

Successful commercialization of nanotechnology (Goal 2) will depend on the scientific quality of research; better understanding of the potential environmental, health, and safety implications of nanotechnology; and cognizance of its relevance and competitiveness in the marketplace. The NNI member agencies will continue to work with academia and across industry sectors to gather input and feedback on Federal research. This continuous engagement will facilitate the effective transition of nanotechnology from discovery to the marketplace. Such engagement could be fostered via means such as matching funds, partnerships, consortia, and planning exercises.

1.4 Develop quantitative measures to assess the performance of the U.S. nanotechnology R&D program relative to that of other major economies, in coordination with broader efforts to develop metrics for innovation.

Nanotechnology is a worldwide field with significant R&D efforts underway in many countries. In order to maintain U.S. leadership, it is critical to develop clearly defined metrics with which to measure the U.S. R&D program against those of other major economies. Efforts to measure innovation are already underway in other areas, and the NNI will leverage that existing work.

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

Significant advances have been made in the fundamental aspects of nanotechnology over the past ten years. While nanotechnology has found its way into commercial products, e.g., in the areas of cosmetics, electronics, and healthcare, a continued emphasis on commercialization is essential to fully realizing the benefits of nanotechnology R&D to the nation. The purpose of Goal 2 is to establish processes to facilitate the responsible (Goal 4) transfer of nanotechnology research (Goal 1) into practical applications and capture its benefits to national security, economic development, and job creation (Goal 3). Successful completion of the objectives of Goal 2 requires close coordination with progress toward the other three NNI goals.

Several factors are necessary to achieve the successful commercialization of any new technology. Scalable, repeatable, cost-effective manufacturing methods are required to move the technology from the laboratory into commercial products. To make commercialization practicable, public and private sector investments are needed to mature technologies and reduce technical risks. Maximizing the benefits of nanotechnology developments to the U.S. economy also requires efforts to remove barriers to global commercialization and an understanding of the potential markets for a given product.

The NNI fosters technology transfer through agencies engaging with key industry sectors to understand their technology needs, providing industry and the public access to the results of Federally funded nanotechnology research, and by helping to support the creation of a business environment conducive to responsible development of nanotechnology. Partners in this undertaking include international, regional, state, and local organizations that promote nanotechnology development, as well as professional societies, trade associations, and other nongovernmental organizations.

Goal 2 Objectives

2.1 Increase support for nanomanufacturing by doubling the Federal investment in nanomanufacturing research over the next five years.

The development of robust, scalable manufacturing methods is necessary to facilitate commercialization of nanotechnologies. This involves a fundamental understanding of the manufacturing process, including the development and application of measurement and characterization techniques, reference materials, and standards. The 2010 review of the NNI by the President's Council of Advisors on Science and Technology[2] recommended a greater emphasis on commercialization by doubling the investment of the Federal government in nanomanufacturing. In addition, the PCAST report recommended the initiation of interagency partnerships, i.e., Signature Initiatives, within the next 3 years. Along these lines, an interagency Signature Initiative in Sustainable Nanomanufacturing is planned for initiation in FY2011.

2.2 Increase focus on nanotechnology-based commercialization and related support for public-private partnerships by:

2.2.1. Launching at least five public-private partnerships over the next five years.

2.2.2. Leveraging the NNI Signature Initiatives (see Goal 1 objectives) to remove barriers to commercialization of nanotechnology innovations, particularly in areas of high national need.

2.2.3. Working with U.S. industry across sectors to develop technology "roadmaps" or long-term R&D plans, as appropriate, in support of new public-private partnerships and signature initiatives.

Many nanotechnology products are moving into commercialization phases, and some NNI member agencies are increasingly collaborating with diverse industry sectors as products are brought to market. The NNI fosters responsible technology transfer through the NSET Subcommittee and its member agencies engaging with key industry sectors and collecting and exchanging information and ideas regarding each sector's technology needs; it also provides a bridge between companies and Federally funded nanotechnology research, strengthening Goal 1 outcomes. This collaborative work could be a market driver, potentially enhancing the U.S. economy and job creation. Such cooperative efforts will be strengthened by supporting public-private partnerships and by an ongoing effort to work with industry as the technology matures. This effort might also help mission-oriented agencies' efforts to expand their applied research and commercialization programs.

2.3 Establish and/or sustain national user facilities, cooperative research centers, and regional initiatives with the goal of accelerating the transfer of nanoscale science from discovery to commercial products by:

2.3.1. Providing economical access by academia and industry, on both precompetitive and proprietary bases, to state-of-the-art tools and processes, expertise, and training that are critical to the transition from discovery to advanced prototype, with options for remote use when feasible.

2.3.2. Supporting the establishment over the next five years of at least three self-sustaining cooperative research centers and/or state and regional economic development initiatives for nanotechnology.

Over the past decade, NNI member agencies have made considerable investments in the development of unique national facilities to support nanotechnology R&D. These investments need to be continued in order to maintain the existing infrastructures as well as add new capabilities to support both basic research in nanotechnology and commercialization efforts. Further efforts to promote nanotechnology commercialization can be supported through continuing the development of Government-university-industry consortia and economic development initiatives at the state or regional level. The NNI will continue to serve as a nucleus for coordination among regional, state, and local nanotechnology initiatives through activities such as the three past NNI workshops that provided a forum for communication and collaboration in this community.

[2] See Appendix A.

2.4 Assist the nanotechnology-based business community, including small- and medium-sized enterprises, in understanding the Federal Government's R&D funding and regulatory environment, by:

2.4.1. Developing and disseminating informational materials documenting funding opportunities (e.g., in the SBIR and STTR programs), state-of-the-art nanotechnology user facilities that are available to industry, and other resources available from the Federal Government.

2.4.2. Providing informational materials, including points of contact, to explain issues such as environmental, health, and safety regulations and export controls pertinent to nanotechnology-related products and businesses.

NSET member agencies recognize the need to make the business community aware of Federal government resources that are available for helping foster nanotechnology-based commercialization and economic development efforts, and of the Federal regulations that may apply to these efforts. Small and medium-sized businesses in particular may not have Washington, DC, offices with specialized expertise related to Federal resources and regulations.

2.5 Increase international engagement to facilitate the responsible and sustainable commercialization, technology transfer, innovation, and trade related to nanotechnology-enabled products and processes, by:

2.5.1. Increasing the participation of NNI member agencies, when appropriate, in forums addressing global legal, intellectual property, and regulatory issues related to nanotechnology-enabled product development.

2.5.2. Enhancing interagency communication and collaboration towards assuring safe nanotechnology-enabled products for domestic and international consumers, through activities such as developing documentary standards.

The successful commercialization of R&D products in domestic and global markets is dependent on adequately addressing issues such as intellectual property (IP), return on investment, and environmental, health, and safety regulations and concerns. NNI member agencies' continued involvement in activities related to these issues is needed to not only ensure a safe environment but also to maintain a level playing field for all involved. For example, ongoing interagency support of development of U.S. and international documentary standards will facilitate such innovation and product development. Successful commercialization also involves the purposeful integration of the aims of each of the other goals in areas such as safeguarding research and IP investment (Goal 1), maintaining a highly skilled workforce (Goal 3), and ensuring responsible and sustainable development, including environmental benefits (Goal 4).

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

Fundamental to the continued successful development of nanotechnology is the development of the resources necessary to support this effort. A substantial investment, strengthened by and dependent on interagency cooperation and collaboration through the NNI, is needed to develop the talent and resources necessary to achieve the other NNI goals of advancing a world-class R&D program (Goal 1), fostering the transfer of new technologies into products for commercial and public benefit (Goal 2), and supporting responsible development of nanotechnology (Goal 4).

Nanotechnology is emerging amid a transformative phase in education in the United States when there is a widely recognized need to improve science, technology, engineering, and mathematics (STEM) education. The creation in the U.S. of a world-leading science and technology workforce, including careers in biomedical science, can be accelerated by nurturing students' fascination with and interest in STEM topics. Not only do core science concepts underpin nanoscale science and engineering, but the

emergence of new properties and behaviors at the nanoscale (often at the intersections of traditional disciplines) can create a "wow" factor to inspire students to learn about nanotechnology and STEM, more broadly. Innovations in nanotechnology can be exploited as vehicles for learning and teaching STEM subjects that students have traditionally found to be too theoretical and therefore uninteresting.

The NNI continues to foster educational programs that develop scientists, engineers, technicians, and production workers through multidisciplinary academic programs, industrial partnerships and Federally funded R&D systems. Extensive infrastructure capabilities, which include the centers and user facilities supporting research on nanomanufacturing, nanoscale characterization, synthesis, simulation, and modeling that have been developed through the NNI over the past ten years, will continue to be advanced. For the NNI to meet the goals outlined in this plan, it will be essential in the coming years to connect and coordinate the vast array and amount of information pertaining to nanotechnology.

Goal 3 Objectives

3.1 Initiate, develop, support, and sustain programs for educating, training, and maintaining a skilled nanotechnology workforce.

Based on the maturing R&D incubation cycle for a number of nanotechnology-enabled products and application areas, there is now a demand for technicians and research scientists to work in nanotechnology-related industries. With the support of NNI centers, colleges and universities have been offering undergraduate minors and majors, teacher training, and postgraduate programs in nanoscale science and engineering. In order to prepare high school graduates for careers in nanotechnology-related industries, the NNI member agencies will work collaboratively to support the development of K–12 STEM (and related, including biomedical) curriculum standards and articulation plans that incorporate problem-based and integrative teaching, where appropriate. International standards and best practices will help to inform these developments. Information on nanotechnology and nanoscience-based career opportunities and workforce needs will strengthen the pursuit of this objective. Online resources should be utilized to help disseminate information on nanotechnology careers and formal education programs in nanotechnology.

3.2 Initiate outreach and informal education programs and publish related information to foster a student population, workforce, and public who are well informed about the opportunities in nanotechnology-related industries and the potential impacts of environmental, health, and safety (EHS) and ethical, legal, and societal implications (ELSI) of nanotechnology.

The information technology (IT) revolution reached the public through its use in virtually all aspects of our lives. Whereas "IT" has become a commonplace term associated with specific applications, the technology behind nanotechnology-enabled products may result in tremendous enhancements or entirely new product properties that might not be explicitly referred to as "nano." Multiple communication tools (e.g., print media, online webcasts and podcasts, museum exhibits, and special events) will be used to achieve this objective.

3.3 Provide, facilitate the sharing of, and sustain the physical R&D infrastructure for nanoscale fabrication, synthesis, characterization, modeling, design, computation, and hands-on training for use by industry, academia, nonprofit organizations, and state and Federal agencies, by:

3.3.1. Determining the current capacity and inventory of tools, facilities and supporting infrastructure, and staffing and services that are available, and determining the capacity requirements up to the year 2020.

3.3.2. Developing, operating, maintaining, and sustaining highly advanced tools, infrastructure, and user facilities (including investment, staffing, and upgrades).

Robust nanotechnology R&D and technical advancement will require the support of a state-of-the-art physical infrastructure that is widely accessible. The specialized capability, equipment, and structures

needed for nanoscience R&D are prohibitively expensive for small enterprises and educational institutions. Sustained and predictable access to a broad range of state-of-the-art instrumentation and facilities for synthesis, processing, fabrication, characterization, modeling, and analysis of nanomaterials and nanosystems, including bio-nanosystems, is needed to achieve this objective. In most cases, no single researcher or even single institution can justify funding the acquisition of and support for all necessary tools, and therefore user facilities that provide access to researchers from multiple sectors, including academia and industry, serve a critical role. Such facilities have the ability to co-locate a broad suite of necessary nanotechnology tools, to maintain these tools at the leading edge, and to provide staff with expertise to ensure the most productive use of the tools. In addition, they provide an outstanding setting for hands-on training of nanotechnology researchers, thereby yielding a skilled workforce.

The extensive infrastructure established by the NNI over the past ten years will be upgraded and sustained by evaluating the need and capacity requirements. International best practices will be incorporated into the current infrastructure, as appropriate. Extensive publicity and dissemination of information will help to reach the nanotechnology sector, especially small and medium enterprises, to ensure that this infrastructure is accessible to all and well utilized.

Goal 4: Support responsible development of nanotechnology.

Responsible development of nanotechnology is central to advancing a world-class R&D program (Goal 1), educating the workforce and engaging the public (Goal 3), and all aspects of nanomanufacturing and product commercialization (Goal 2). To help integrate responsible development across the spectrum of nanotechnology, the NNI has developed, with input from stakeholders, an environmental, health, and safety (EHS) research strategy with a broad, multi-agency perspective.[3] Research in support of Goal 4 provides information and data for research institutions, regulatory agencies, the public, and industry, helping to assure that nanotechnology-enabled products minimize adverse impacts and maximize benefits to humans and the environment.

The Goal 4 objectives track progress in responsible development and are divided into four different yet integral sections: public health and environmental protection; domestic and international engagement; ethical, legal, and societal implications of nanotechnology; and solutions for critical public health and environmental challenges.

Goal 4 Objectives

4.1 Incorporate safety evaluation of nanomaterials into the product life cycle, foster responsible development, and where appropriate, sustainability across the nanotechnology innovation pipeline, by:

4.1.1. Developing and applying:

- Measurement tools (defined as protocols, standards, models, data, and instruments) to assess the physico-chemical properties of engineered nanoscale materials and their biological effects in the environment and on human health and to quantify exposure across the nanotechnology product life cycle.
- Models, including risk assessment models, to assess safety of nanomaterials throughout the life cycle of the material or product.

[3] See the *Federal Strategy for Nanotechnology-Related Environmental Health and Safety Research*, available in 2010/2011 at http://nano.gov. This strategy, informed by a series of four EHS-themed stakeholder workshops in 2009–2010, consists of comprehensive planning, research coordination, and a review of research needs and accomplishments.

- Health surveillance models as appropriate for the nanotechnology workforce, consumers, susceptible populations, and the environment.

4.1.2. Creating mechanisms for appropriate and timely information sharing and dissemination among stakeholders, including academia, industry, legal entities, Federal agencies, regulatory communities, the general public, and other relevant stakeholders.

4.1.3. Establishing guidance, standards, or other methods to formulate nanotechnology-related regulatory approaches for domestic and global researchers, manufacturers, distributors, and users of nanotechnology-enabled products to ensure the protection of public health and the environment.

In support of this objective, the NNI Strategy for Nanotechnology-related Environmental, Health, and Safety Research[4] *("EHS Strategy") provides a research framework, including exposure and hazard identification across the nanomaterial and product life cycle, by identifying core research needs in the areas of human exposure, the environment, human health, and measurement tools. The 2010 NNI EHS Strategy is complemented by risk assessment and risk management approaches along with research needs in predictive modeling. It serves as guidance to Federal agencies as they develop their agency-specific nanotechnology EHS strategies and implementation plans.*

4.2 Develop tools and procedures for domestic and international outreach and engagement, by:

4.2.1. Identifying information gaps and prioritizing research to focus on obtaining information essential for risk communication and risk management to address potential occupational and product hazards for start-up and larger companies working with nanoscale materials and processes.

- Assuring adequacy of workforce training and risk communication strategies through active outreach and engagement.
- Increasing available information for better decision making in assessing and managing risks from nanoscale materials.

4.2.2. Obtaining stakeholder perspectives by developing and using a variety of methods, such as surveys, workshops, public meetings, and advisory panels; disseminating information through publicly accessible summaries of findings; and developing mechanisms for integration of EHS priorities and assessment methods into national and international regulatory policies.

4.2. 3. Communicating available information about assessing and managing potential risks from nanoscale materials and about nanotechnology-related regulatory approaches to both domestic and global manufacturers.

4.2.4. Increasing U.S. participation internationally in bilateral and multilateral forums and organizations that address stakeholders' concerns surrounding the development of nanotechnology by providing information, guidance, training, and capacity-building resources for governments.

The NNI Strategy for Nanotechnology-related Environmental, Health, and Safety Research[5] *provides details on how the NNI can better disseminate knowledge and engage internationally in the area of EHS research. As described in the EHS strategy, Federal agencies actively engage with other countries on a bilateral and multilateral basis to help further this objective.*

4.3 Identify and manage the ethical, legal, and social implications (ELSI) of research leading to nanotechnology-enabled products and processes, by:

[4] Available at http://nano.gov, the latest strategy is slated for release in December 2010 / January 2011.
[5] Available at http://nano.gov, the latest strategy is slated for release in December 2010 / January 2011.

4.3.1. Building collaborations among the relevant expert communities, such as regulators; ethicists; engineers; scientists, including social and behavioral scientists; nongovernmental organizations; industry; and consumers, in order to support a rapid mobilization of stakeholders to consider the potential risks and benefits of research breakthroughs and provide perspectives on new research directions.

4.3.2. Increasing the capacity of Federal agencies and ELSI communities to identify and address ELSI issues specific to nanotechnology by creating and maintaining a resource list of experts in ELSI and nanotechnology that is accessible to a broad range of users.

4.3.3. Developing information resources for ethical and legal issues related to intellectual property (IP), IP litigation, and ethical implications of nanotechnology-based patents and trade secrets.

ELSI issues are interwoven with the research needs described in the NNI Strategy for Nanotechnology-related Environmental, Health, and Safety Research,[6] *to help Federal agencies consider stakeholder concerns when identifying research areas and establishing decision analysis methodologies.*

4.4 Employ nanotechnology and sustainable best practices to protect and improve human health and the environment, by:

4.4.1. Supporting research to incorporate environmentally benign methods into manufacturing processes.

4.4.2. Developing technologies to assess the status of human health and ecosystems.

4.4.3. Fostering the use of nanomaterials to replace or reduce commonly-used compounds that have known adverse effects on human health and the environment.

4.4.4. Creating and implementing methods, nanomaterials, and nanotechnology-enabled devices to reduce human and environmental exposures to harmful compounds.

Nanotechnology can play a role in resolving societal challenges such as access to safe food and water, secure living and work environments, clean and renewable energy, and diagnosis and treatment of diseases or medical disorders. Research directed at applications is complementary to EHS research; the support of both is needed to realize the NNI goal of responsible nanotechnology development.

[6] Available at http://nano.gov, the latest strategy is slated for release in December 2010 / January 2011.

Coordination & Assessment

The NNI is coordinated, planned, implemented, and reviewed by the Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the Committee on Technology (CT) of the National Science and Technology Council (NSTC). Other components of NNI coordination include four thematic NSET working groups (described below), the National Nanotechnology Coordination Office (NNCO), and the Executive Office of the President (EOP). Periodic assessment of the NNI by external advisory bodies provides additional input and guidance to the NNI. Figure 1 shows the various entities that play a role in NNI coordination and assessment activities and their relationships to each other. The roles of the various entities and their interactions are further described below.

Nanoscale Science, Engineering, and Technology Subcommittee

The beginnings of the NNI can be traced to September 1998, when the NSET Interagency Working Group on Nanotechnology was formed. This working group sponsored workshops and studies to define the state of the art in nanoscale science and technology and to forecast future developments. Two years later, this effort was raised to the level of a Federal initiative. The Nanoscale Science, Engineering, and Technology (NSET) Subcommittee was then established under the NSTC's Committee on Technology to serve as the body responsible for interagency coordination of nanotechnology R&D activities. The National Nanotechnology Coordination Office was subsequently established as the point of contact on Federal nanotechnology R&D activities and to provide technical and administrative assistance to the NSET Subcommittee.

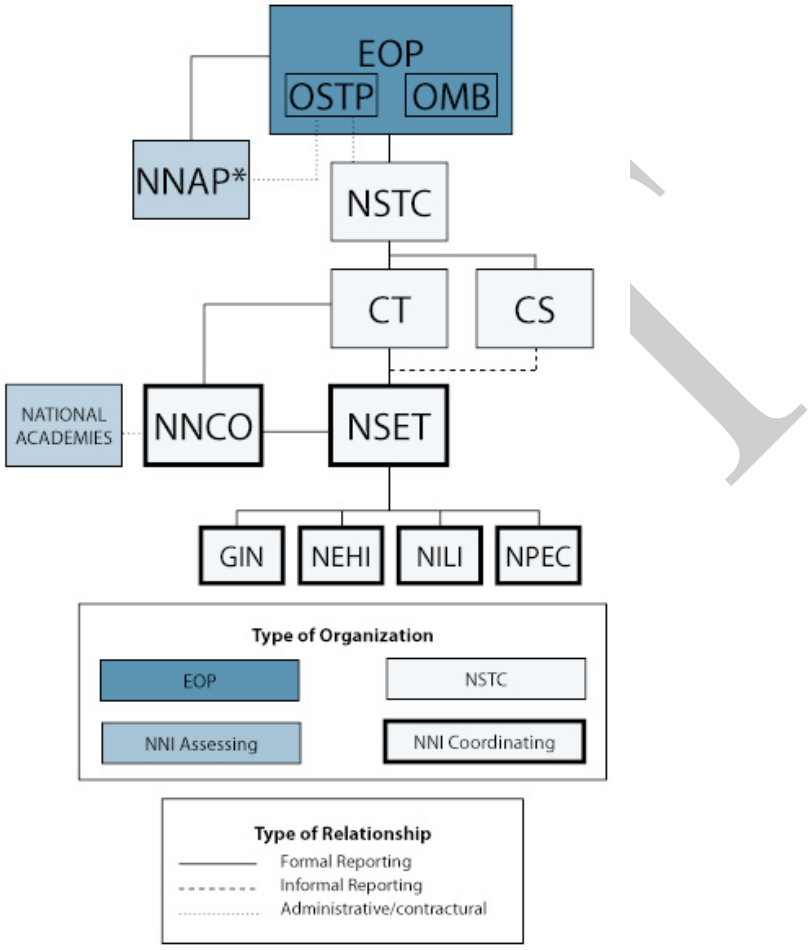
The importance of a coordinated Federal program for nanotechnology R&D was further recognized with the enactment of the 21st Century Nanotechnology Research and Development Act in December 2003 (hereafter referred to as "the Act"). This legislation authorized appropriations for nanotechnology research, formalized many of the coordination structures that the NSTC had organized, and established additional mechanisms to ensure that the Government developed sound, informed nanotechnology R&D strategies and policies. This legislation also created the National Nanotechnology Advisory Panel (NNAP), called for a triennial review of the NNI by the National Research Council of the National Academies (NRC/NA), and established specific functions for the NNCO.

The NSET Subcommittee leads the interagency coordination of the Federal Government's nanotechnology R&D enterprise by serving as a forum for the agencies that participate in the NNI to cooperatively execute the research, development, communication, and funding functions of the NNI. The NSET Subcommittee performs many of the coordination activities of the NNI, such as developing the NNI Strategic Plan, preparing the NNI supplement to the Presidential Budget, and sponsoring workshops that inform the Government's nanotechnology-related decision-making processes.[1] Each agency participating in the NNI is represented on the NSET Subcommittee; a list of those agencies is given at the front of this report. A co-chair from the Office of Science and Technology Policy (OSTP) and a co-chair from an NNI agency lead the NSET Subcommittee. It meets at least six times each year.

The member agencies of the NNI, working through the NSET Subcommittee, establish broad goals, identify priorities, and formulate plans for the NNI. This high-level framework, in turn, guides and informs the member agencies in developing their nanotechnology R&D implementation plans. The NSET Subcommittee also plans and sponsors interagency activities aimed at achieving the NNI goals. The subcommittee promotes balanced investment across all of the agencies, to address the critical elements

[1] Access to information on all NNI-sponsored workshops and complete versions of all reports and related NNI documents are available at http://nano.gov.

needed to support the development and utilization of nanotechnology. The subcommittee interacts with pertinent academic, industry, state, and local government groups, and with international organizations. The NSET Subcommittee also keeps the NSTC's Committee on Science (CS) and Committee on Technology informed of its activities.



*Executive order 13349 designates the President's Council of Advisors on Science and Technology (PCAST) as the National Nanotechnology Advisory Panel (NNAP).

Figure 1. Coordination and assessment of the NNI.

Working Groups of the NSET Subcommittee

The NSET Subcommittee has chartered four working groups to provide a structure to help improve the efficiency of the subcommittee and its member agencies, focused on areas of greatest need that the subcommittee recognizes will benefit from focused interagency attention and activity: Global Issues in Nanotechnology; Nanotechnology Environmental and Health Implications; Nanomanufacturing, Industry Liaison, and Innovation; and Nanotechnology Public Engagement and Communications. The NSET's periodic assessment of these working groups in terms of focus, intended participation, and scope is reflected in the groups' charters, which are reviewed on a regular basis prior to renewal.

Global Issues in Nanotechnology (GIN) Working Group

Sustained commitment to robust international engagement is needed in order to realize the NNI vision. The NSET Subcommittee's Global Issues in Nanotechnology (GIN) Working Group coordinates

international activities in nanotechnology and seeks to broaden international cooperation and communications with respect to nanotechnology R&D. The GIN Working Group, consisting of representatives from Federal agencies with active nanotechnology R&D programs as well as from agencies that have oversight roles in international affairs, helps to support each of the four NNI goals by focusing on R&D collaboration, international capacity building, and engagement with domestic and international partners on regulatory and trade issues. NNI agencies participate in many international activities, including bilateral and multilateral R&D cooperative programs, monitoring of foreign nanotechnology R&D, and promotion of the trade and commercial interests of the United States. Collaboration with other nations on nanoscale science and technology R&D in areas of mutual interest can further the progress of the NNI while helping international partners to realize their own goals.

International cooperation is important to ensuring that concerns surrounding the use of nanotechnology-enabled products (e.g., environmental, health, safety, security, and societal issues) are addressed globally as appropriate. Effective communication and partnerships are needed internationally among all interested stakeholders, including scientists, regulators, policymakers, consumers, and industrial leaders. The development of a healthy global marketplace for nanotechnology products and ideas will require the establishment of consumer confidence; common approaches to nanotechnology-related environmental, health, and safety issues; efficient and effective regulatory schemes; and equitable trade practices for nanotechnology, not just in the United States, but worldwide.

Nanotechnology Environmental and Health Implications (NEHI) Working Group

In order to fully realize the anticipated transformational potential of nanotechnology, it is important for Federal agencies to provide guidance on the safe use and handling of engineered nanoscale materials in the laboratory, in manufacturing, in the workplace, in consumer products, and in the environment, as well as to understand potential environmental, health, and safety impacts of nanotechnology. NNI activities provide channels for the exchange of information and the formulation of research strategies that accelerate progress towards understanding the risks and benefits of nanotechnology and that lead to practices that protect human health and the environment. The NSET Subcommittee's Nanotechnology Environmental and Health Implications (NEHI) Working Group provides a forum for interagency collaboration and coordinates many of the NNI activities in this area.

The NSET Subcommittee and NEHI Working Group provide leadership in establishing the national nanotechnology environmental, health, and safety research agenda and in communicating data and information related to environmental and health aspects of nanotechnology between NNI agencies and with the public. New tools and methods are required for the research to enable risk analysis and assist in regulatory decision making, and NNI activities support the development of these tools and methods. All these activities require nanotechnology standards, including standard nomenclature and terminology, and participating NNI agencies work with consensus-based standards organizations to develop standards for nanotechnology. The outcome of this research, data collection, and tool and standards development is the information that provides the basis for the drafting of guidance in the safe handling, use, and disposal of nanotechnology-derived materials and products by researchers, workers, and consumers.

The combined efforts of many sectors of the R&D community are required to address the environmental, health, and safety research priorities to strengthen the scientific foundation of risk assessment and risk management of nanotechnology-enabled products. The NNI agencies engage and interact with regional, state, and local groups, educational institutions, industry-supported groups, other governments, and nongovernmental organizations, using the NEHI Working Group and the NSET Subcommittee to coordinate, as appropriate. Interactions between the research community and the entities using the data collected in nanotechnology environmental, health, and safety research enhances the value of NNI efforts and provides a collaborative approach.

Nanomanufacturing, Industry Liaison, and Innovation (NILI) Working Group

Technology innovation is a key to realizing the NNI vision. In partnership with industry and state organizations, the NNI supports the nanotechnology innovation ecosystem by fostering alliances among all the players in the innovation process, from researchers to industrial leaders, regulators, and investors. The NSET Subcommittee's Nanomanufacturing, Industry Liaison, and Innovation (NILI) Working Group coordinates many of the NNI activities in this area. Examples include partnering NNI member agencies with industry groups; developing a database of nanotechnology-related programs across agencies; periodically organizing workshops that bring together national, regional, state, and local stakeholders; and supporting the NNI Signature Initiative on Sustainable Nanomanufacturing.

The NILI Working Group promotes U.S. leadership in the creation of new products and manufacturing processes derived from discovery at the nanoscale. The NILI group also creates mechanisms to facilitate nanotechnology innovation and to improve technology transfer to industry, and it promotes the exchange of information among Federal agencies, academia, and state, regional, and local organizations. Within the Federal Government, this effort includes interagency cooperation in the areas of nanotechnology-related standards, nomenclature, nanomanufacturing research, and programs that encourage innovation in small businesses.

Industry liaison groups are a key tool in this undertaking because they are a conduit for partnerships between the NNI and industry sectors. These liaison groups generally represent particular industries, for example, electronics, chemicals, or forest products. Formation of such an industrial liaison group is open to any industrial sector. These groups review the status of relevant nanotechnology R&D and recommend new R&D directions and activities; work to identify best technology transfer practices; and foster development of nanotechnology standards, terminology, nomenclature, and measurement and characterization methods.

Nanotechnology Public Engagement & Communications (NPEC) Working Group

The NNI recognizes that the perspectives of public and stakeholder groups are vital in the nanotechnology R&D enterprise and considers effective public engagement and outreach to be one of its key objectives. The NSET Subcommittee's Nanotechnology Public Engagement and Communications (NPEC) Working Group, in conjunction with the NNCO, coordinates many of the NNI activities in this area.

The NPEC working group encourages, coordinates, and supports NNI member agencies and interagency efforts toward educating and engaging the public, policymakers, and stakeholder groups about nanotechnology, its applications and implications, and the work of the NNI. The NPEC also facilitates the identification, prioritization, and implementation of activities involving public outreach, engagement, and communications on behalf of the NSET Subcommittee by promoting responsible communication of research results and other topics of special interest, including environmental, health, and safety issues; ethical, legal, and social implications issues; and public outreach and engagement.

To enable better communication among the NSET Subcommittee and its working groups, individual member agencies, and the NNCO, NPEC assists in the development of information and guidance for communications activities and supports the development of best practices for outreach and engagement among governmental and nongovernmental organizations, the public, and other stakeholders regarding the responsible development of nanotechnology.

National Nanotechnology Coordination Office (NNCO)

The National Nanotechnology Coordination Office (NNCO) is a pivotal locus for NNI activity, providing technical and administrative support for the NSET Subcommittee, serving as a central point of contact for Federal nanotechnology R&D activities, including those of the four NSET working groups, and performing public outreach and engagement on behalf of the NNI.

The NNCO organizes and plans for meetings of the NSET Subcommittee and its working groups, providing staff members to serve as central points of contact and to record and maintain minutes of the meetings. The NNCO also organizes NNI-sponsored workshops and prepares and publishes reports of those workshops. It coordinates the preparation and publication of NNI interagency planning, budget, and assessment documents, such as the annual NNI supplement to the President's Budget. The NNCO serves as a Congressional liaison by coordinating the development of information on the NNI and its activities for Congress when requested.

The NNCO produces and distributes information for the general public, including brochures, workshop reports, nanotechnology-related news, educational resources, funding opportunities, and other information, all of which are made available at the NNI website, http://nano.gov. This website, which is designed, organized, and maintained by the NNCO, also provides information about recent developments in nanotechnology and NNI activities. The NNCO communications effort is strengthened by relationships between NNCO staff and key press contacts and public information officers at NSET member agencies. NNCO staff members prepare and deliver presentations and lectures on NNI activities at professional society meetings and a wide variety of public venues. The NNCO will continue to organize diverse public input and outreach activities; future examples may include interactive web dialogues, citizens' panels, workshops, and other educational events. The NNCO Director and Deputy Director act as the primary liaison for independent assessment of the NNI by arranging for the triennial review of the NNI by the National Research Council of the National Academies.

Contributions from the NSET Subcommittee member agencies fund the NNCO. The White House Co-Chair of the NSTC Committee on Technology appoints the NNCO Director, in consultation with the Co-Chairs of the NSET Subcommittee. In accordance with the Act, the NNCO Director is detailed from a Federal agency to the NSTC as an agency representative and reports to the White House Co-Chair of the NSTC Committee on Technology. The NNCO Deputy Director is also detailed from a Federal agency and has been named as the coordinator for environmental, health, and safety.

Executive Office of the President

Representatives from the Executive Office of the President participate in NNI activities to ensure that implementation of the NNI is coordinated and consistent with Government-wide priorities. The primary points of interaction are the Office of Science and Technology Policy and the Office of Management and Budget (OMB).

OSTP is responsible for advising the EOP on matters relating to science and technology and supports coordination of interagency science and technology activities. OSTP administers the NSTC, and the OSTP representative to the NSET Subcommittee is a co-chair of the subcommittee. This arrangement provides EOP-level input on and support for various NNI activities.

OMB is responsible for coordinating with the NNI member agency budget offices to establish the nanotechnology R&D budget for planning and tracking purposes. Each year, OMB collects budget information regarding the total Federal investment in nanotechnology R&D, as well as information about agency investments within each program component area.

Assessment

The Act calls for periodic assessment of the NNI through annual interagency reporting and review by external advisory bodies. This annual interagency analysis of progress called for in the Act is provided in the NNI supplement to the President's Budget, which also serves as the NNI annual report called for in the Act. Specifically, progress towards achieving NNI goals and priorities is analyzed in terms of (1) investments by PCA, including cross-cutting interagency activities coordinated through NSET Subcommittee, and (2) activities relating to the four NNI goals. Goal-related activities are individual

agency activities and coordinated activities with other agencies and other institutions, including international interactions.

Review by outside advisory groups is vital to keeping NNI efforts focused and balanced, and the Act established two mechanisms for such review. First, the Act calls for the President to establish a National Nanotechnology Advisory Panel (NNAP) to advise the President and the NSTC on matters relating to the NNI. The Act specifically calls for the NNAP to assess the Federal nanotechnology R&D program at least once every two years. Executive Order 13349 (year) designates the President's Council of Advisors on Science and Technology (PCAST) as the NNAP. The members of PCAST are senior representatives from industry and academic research institutions who have extensive experience in managing large science and technology organizations. Second, the Act calls for the NRC/NA to review the NNI every third year. The NRC/NA panel for the NNI reviews is comprised of a broad cross-section of technical experts with knowledge specifically related to nanotechnology. The NRC/NA provides independent science, technology, and health policy advice to the Government. It is the principal operating agency of the National Academies in providing services to the government, the public, and the scientific and engineering communities.

The first assessment by PCAST in its role as the NNAP was released in May 2005, and the first NRC/NA review was completed in November 2006. Subsequent reviews from PCAST were completed in April, 2008, and March, 2010. The NRC/NA delivered its second triennial report assessing the Federal strategy for nanotechnology-related environmental, health, and safety research in December 2009. The perspectives of these two bodies, and their assessments, are complementary, and the NNI has benefited from their diverse inputs into the planning and evaluation process. The resulting recommendations have led to specific actions and focused attention in areas that were highlighted by both groups, including research on environmental, health, and safety aspects of nanotechnology and expanded efforts to improve education and workforce preparation as well as program management.

The Path Forward

The full realization of the promise of nanotechnology as supported by the NNI and its member agencies will continue to rely on the hallmark activities of the NNI: namely, to nurture coordination, collaboration, and communication among participating Federal agencies. In this area, means for improved intra-agency communication across all levels of management will be explored. Participating agencies will be identifying opportunities for enhanced engagement of agencies with stakeholders in the nanotechnology community— including regional, state, and local initiatives in nanotechnology and representatives from industrial sectors, nongovernmental organizations, and standards organizations at the national and international levels—as well as seeking mechanisms for targeted multilateral coordination on specific technical subjects such as water purification. Moving into the next decade, meaningful engagement with stakeholders and ongoing external assessments by other bodies will strengthen the efforts of the NNI as the participating agencies move toward realizing the four NNI goals.

Collaborative Agency Activities

As a multi-agency body, the NSET Subcommittee coordinates and collaborates on a variety of activities and efforts. Among these efforts are signature initiatives that target multi-agency resources toward mutually agreed-on scientific and technological goals; development of joint research solicitations; and a wide variety of interagency meetings, workshops, and forums. In addition, member agencies work individually or in multi-agency collaborations in support of various R&D initiatives and unique facilities. The participation of member agencies in these activities varies with the relevance of any specific activity to the Agency's mission and goals; overall, agency participation is anticipated to continue as the NNI advances.

Nanotechnology Signature Initiatives

To accelerate nanotechnology development in support of the President's priorities and innovation strategy, the OSTP and NNI member agencies have identified areas ripe for significant advances through close and targeted program-level interagency collaboration. This collaboration now includes so-called "signature initiatives" that are intended to enable the rapid advancement of science and technology by targeting resources towards critical challenges and R&D gaps. These activities also leverage skills, resources, and capabilities among various agencies in a concerted effort to attain scientific and technological advances. The signature initiatives are intended to genuinely affect the agency budget process, as encouraged by Administration guidance, and to dramatically improve ground-level functional coordination between agencies. The interagency working group supporting each initiative will identify thrust areas within each of the proposed initiative topics, identify specific agency programs that are involved, and what additional funding, if available, is needed. The NSET Subcommittee anticipates incorporating participation and input from industry and other stakeholders on current and future Nanotechnology Signature Initiatives. The first three signature initiatives[13] are described in Table 3.

These Nanotechnology Signature Initiatives represent the leading edge of functional interagency collaboration in the budget and program planning process under the NNI, with multiple agencies working in common toward specific objectives.

[13] See http://nano.gov for the latest information on these initiatives. Table 3 contains a high-level summary of each initiative at the time of the publication of this document.

Table 3. Nanotechnology Signature Initiatives proposed in FY 2011

Nanotechnology for Solar Energy Collection and Conversion	Agencies involved: DOE, NIST, NSF, DOD, IC/DNI, USDA/NIFA

The President's Agenda calls for the development of carbon-neutral alternative energy sources to mitigate global climate change, reduce dependence on foreign oil, improve the economy, and improve the environment. The specific targets state that 10 percent of electricity generated should be derived from renewable sources by 2012 and 25 percent by 2025. Solar energy is a promising alternative energy source that can address these challenges. It is readily available, free from geopolitical tension, and not a threat to the environment through pollution or to the climate through greenhouse gas emission. The development of a solar energy infrastructure will not only support U.S. energy independence but also represents an unparalleled economic opportunity if the United States can maintain scientific and industrial leadership in this field. Today, the levelized cost of energy of solar technology is not yet economically competitive with conventional fossil fuel technologies without subsidies. Therefore, new innovations and fundamental breakthroughs can help accelerate the development of economical solar energy technologies that surpass the limits of existing technologies. Nanotechnology can help overcome current performance barriers and substantially improve the collection and conversion of solar energy. At the nanoscale, a number of physical phenomena have been identified that can improve the collection and conversion of solar energy. Nanoparticles and nanostructures have been shown to enhance the absorption of light, increase the conversion of light to electricity, and provide better thermal storage and transport. However, current demonstrations of these technologies fall short of potential performance because of poor control over feature size and placement, unpredictable micro/nanostructure, poor interface formation, and in many cases, short lifetimes of laboratory devices. The goal of this initiative is to exploit the benefits of nanotechnology by enhancing understanding of conversion and storage phenomena at the nanoscale, improving nanoscale characterization of electronic properties, and helping enable economical nanomanufacturing.

Sustainable Nanomanufacturing – Creating the Industries of the Future	Agencies involved: NIST, NSF, DOE, DOD, EPA, IC/DNI, NIOSH/OSHA, USDA/FS

The promise of establishing a significant number of new, high-value industries based on the past decade of investment in the NNI will only be realized if suitable manufacturing technologies can be developed to economically and reliably produce nanotechnology-based products on a commercial scale. The semiconductor industry has achieved this, but the production methods are not scalable or economical for the diversity of new materials and products at the volumes and length scales required: radically new approaches are needed. Moreover, for such products to be ubiquitous in the nation's future economy, they and their associated manufacturing processes must be sustainable by design. To create the foundation for achieving this vision, the goal of this initiative is to accelerate the development of industrial-scale methods for manufacturing functional nanoscale systems. The initiative targets production-worthy scaling of three classes of sustainable materials (high-performance structural carbon-based nanomaterials, optical metamaterials, and cellulosic nanomaterials) that have the potential to affect multiple industry sectors with significant economic impact. The formation of industry/government/academic consortia is a key aspect of the specific material thrusts.

An essential prerequisite for the development of cost-effective nanomanufacturing is the availability of high-throughput, inline metrology to enable closed-loop process control and quality assurance. The initiative is therefore focused directly on the development of inexpensive, rapid, and accurate measurement techniques. The United States has expertise in roll-to-roll manufacturing, which can be adapted to the types of high-volume fabrication processes envisioned. The formation of a consortium devoted to the development of metrology methods to enable roll-to-roll application to nanomanufacturing is expected to play an essential role here. The systems to be manufactured, based on these methods, will include disruptive technologies for lightweight, high-strength, sustainable materials, solar energy harvesting, waste-heat management and recovery, and energy storage. Success of the initiative will result in the immediate extension of the methods developed to more complex components and systems as future nanodevices mature and will help secure and strengthen the U.S. manufacturing base.

Nanoelectronics for 2020 and Beyond	Agencies involved: NSF, DOD, NIST, DOE, IC/DNI

The semiconductor industry is a major driver of the modern U.S. economy and has accounted for a large proportion of the productivity gains that have characterized the global economy since the 1990s. Recent advances in this area have been fueled by what is known as Moore's Law scaling, which has successfully predicted the exponential increase in the performance of computing devices for the last 40 years. This gain has been achieved due to ever-increasing miniaturization of semiconductor processing and memory devices (smaller and faster switches and transistors). Continuing to shrink the dimensions of electronic devices is important in order to further increase processing speed, reduce device switching energy, increase system functionality, and reduce manufacturing cost per bit. But as the dimensions of critical elements of devices approach atomic size, quantum tunneling and other quantum effects degrade and ultimately prohibit the operations of conventional devices. Researchers are therefore pursuing more radical approaches to overcome these fundamental physics limitations. Candidate approaches include different types of logic using cellular automata or quantum entanglement and superposition; 3D spatial architectures; and information-carrying variables other than electron charge, such as photon polarization, electron spin, and position and states of atoms and molecules. Approaches based on nanoscale science, engineering, and technology are most promising for realizing these radical changes and are expected to change the very nature of electronics and the essence of how electronic devices are manufactured. Rapidly reinforcing domestic R&D successes in these arenas could establish a U.S. domestic manufacturing base that will dominate 21st-century electronics commerce. The goal of this initiative is to accelerate the discovery and use of novel nanoscale fabrication processes and innovative concepts to produce revolutionary materials, devices, systems, and architectures to advance the field of nanoelectronics.

Joint Research Calls

NSET member agencies develop joint research solicitations in areas of mutual interest. The management of funding opportunity announcements (i.e., Requests for Application and/or Proposals) is typically done by one (lead) agency, with participating agencies contributing research descriptions and names of technical peer reviewers. Following an external peer review, the individual agencies select and support separate research grants that are deemed meritorious. Collaboration early in the process results in well-crafted solicitations that address critical scientific gaps in the identified area. Agencies are also able to leverage resources used to develop, publish, and manage research solicitations, thereby freeing resources for other needs. In some critical areas of mutual interest (e.g., nanotechnology-related environmental, health, and safety research), NSET member agencies have issued joint, bilateral research calls with international governmental research agencies. Such collaborations enable international research partnerships that result in better research outcomes. Future collaborative research solicitations will seek to build on these bilateral research calls and to engage a breadth of partners, including industrial and nongovernmental organizations and governmental research agencies in multiple nations.

Joint Research Facilities

NSET member agencies also develop joint research facilities that can combine strengths and expertise of participating agencies to enable faster and/or greater progress in nanotechnology research and development. One notable example to date is the Nanotechnology Characterization Laboratory, a collaboration of NCI, NIST, and FDA launched in 2005 to accelerate the transition of basic nanoscale particles and devices into clinical use by providing critical infrastructure and characterization services to nanomaterial developers. The development and support of collaborative research facilities going forward will be modeled upon such successful collaborations to enable broader participation from multiple agencies and industrial sectors.

Interagency Meetings, Workshops, and Forums

The NNI membership finds value in events that help bring representatives from multiple agencies together, as well as researchers supported by various agencies, to share knowledge and accelerate progress. NSET members help disseminate information about topical meetings hosted by individual agencies, e.g., annual agency nanotechnology grantee meetings. Where multiple agencies participate in research solicitations, these grantee meetings feature the research progress from many agencies. An example is the EPA, NSF, NIEHS, NIOSH, and DOE Interagency Nano Grantees Workshop, held November 9–10, 2009, in Las Vegas, NV.[14] Moreover, NSET member agencies may lead and co-sponsor studies to evaluate the current trends, opportunities, and gaps in nanoscale science and engineering R&D to aid policies and decisions in the NNI agencies' research investments.[15] Symposia and sessions organized by representatives from member agencies at various professional and technical conferences are also broadcast to the entire NSET community for participation and attendance. A number of NNI member agencies also participate in international member organizations, workshops, and forums, where they help to represent the United States and foster connections to international partners.

Anticipated Activities: Looking Forward

Principally, the continued success of the NNI in the future will encompass a variety of coordinated activities. New activities planned for the immediate future include implementation of additional signature initiatives, working with the broad nanotechnology community to create a robust hub for nanotechnology information, and an effort by the NNI leadership to strengthen support for the NNI throughout the Federal government by engagement of all levels of management.

Building on lessons learned through the planning and implementation of the first three signature initiatives, future initiatives will be developed to address critical research needs and focus areas. As demands on society to sustain itself and the surrounding ecosystem shift and new challenges emerge, the NNI will use signature initiatives as one means of addressing and meeting these challenges using nanotechnology. The continued development of joint research solicitations is another way that the NNI will be able to incorporate emerging issues into its activities. These collaborative activities impart flexibility to the NSET member agencies, enabling them to assess and meet new challenges at the outset.

In the future, SBIR and STTR programs will benefit from joint-agency funding opportunity announcements targeted in areas ripe for the maturation of nanotechnology-enabled concepts. Multi-agency collaboration in support of research facilities will also help advance nanoscale science and engineering. The NNI member agencies will continue to develop the applied science and expertise relevant to regulation needed to support responsible development of nanotechnology-enabled products. These efforts will be supported by the communication and collaboration engendered by the coordinated NNI framework of the NSET Subcommittee and its interagency working groups.

The NNI recognizes the urgent need for an internet-based, "one-stop shop" access point for nanotechnology information. Through this hub, various stakeholders and members of the nanotechnology community should be able to access a wide variety of information portals containing information on nanoscale science and engineering education opportunities, nanotechnology-related careers, nanotechnology-based products, scientific data such as characterization and toxicity measurements, manufacturing instrumentation and resources, regulatory explanations, and other important elements of the nanotechnology enterprise. Participating NNI agencies appreciate this need and are committed to meeting this challenge. Initially, this will be done through individual efforts on the part of the agencies as their specific missions and mandates dictate. Achieving this long-term goal will require the assistance of

[14] For information on inter- and single-agency nanotechnology-related meetings and workshops see http://nano.gov.

[15] One example of such a study is "Nanotechnology Long-term Impacts and Research Directions: 2000–2020," led by NSF and co-sponsored by other NNI participating agencies (see details at http://wtec.org/nano2/#Background).

stakeholders from industry, academia, nongovernmental organizations, and state and local governments, among others. International organizations and governments will also have a role to play in the establishment of a robust nanotechnology "hub."

The NNI member agencies, with help from the NNCO, plan to strengthen support for the NNI throughout all levels of the Federal government, from the Executive Office to the NNI member agencies to individual researchers at Federal agencies, through a number of actions, including:

- Performing an ongoing mapping exercise to evaluate how this strategic plan relates to member agencies' strategic plans and administration priorities.
- Holding meetings between the NNI leadership (NSET Subcommittee Co-Chairs, OMB NSET Representative, NNCO Director, Working Group Co-Chairs) and top-level management of each NNI member agency, to facilitate and strengthen agency support for the NNI, to discuss how the NNI activities can integrate better with R&D programs of the agency, and to become better informed about the goals and activities of each member agency with respect to nanotechnology.

Finally, NNI member agencies will continue to identify formal and informal mechanisms to overcome obstacles to interagency collaboration, which can arise due to differing agency needs, missions, cultures, and processes. Within these limitations, efforts will be encouraged to nurture relationships by drawing upon knowledge and expertise across agencies and by detailing agency staff to the NNCO. These activities help to strengthen connections between agencies and support the NNI vision. Agencies are also individually encouraged to explore new forms of partnerships and collaborations.

Developing Partnerships and Engaging Stakeholders

As described in the Goals and Objectives section of this document, engagement with an array of stakeholders is considered to be critical to the future success of the NNI. The NNI will pursue effective methods to create and foster public–private partnerships. Future plans for stakeholder engagement will involve the use of Web 2.0 tools and interactive platforms, such as the NNI Strategy Portal.[16] Policy tools, such as prizes and challenges sponsored by one or more Federal agencies, can help spur nanotechnology innovation by engaging entrepreneurs, investors, universities, foundations, and nonprofit organizations. Furthermore, NNI member agencies will continue to participate in international standards organizations and multilateral forums to address policy-relevant nanotechnology issues and to promote international cooperation in aspects of nanotechnology that might affect human health and environmental safety.

Planned External Reviews

The NNI is regularly reviewed by external advisory bodies. Recent reviews by PCAST and the NRC/NA have served to inform the strategic planning of NNI in both this document and the 2010 Federal strategy for nanotechnology-related EHS research. The next NNAP review of the NNI is scheduled for 2012 under the current terms of the Act; the next NRC/NA assessment is scheduled for FY 2011.

Concluding Remarks

As indicated by the objectives outlined under the four NNI goals, the NSET member agencies have developed this strategic plan as a means of moving toward achieving the NNI vision. Initially assessing the strengths, weaknesses, and opportunities facing the NNI as it enters its eleventh year, the NSET Subcommittee devised this plan as a guide. By making concerted and coordinated efforts towards these goals through the stated objectives, the NNI agencies can together realize a vibrant nanotechnology research and development program. Continual assessment of progress is planned, in addition to the in-

[16] http://strategy.nano.gov is an online community that was originally established as a portal to solicit public input into this NNI Strategic Plan.

depth review and analysis that occurs every three years when the strategic plan is revised. The ultimate aim of this plan is to enable the NNI to move the country towards a strong, healthy, and prosperous future, capitalizing on the potential of nanotechnology as a stepping stone to attain this promise.

Over the next 10 years, we will continue to see new nanotechnology-enabled products, systems, and procedures with significant improvements in performance and functionality. At the same time, continued support for fundamental nanotechnology R&D and an awareness of responsible development will lead to new discoveries. Aside from the need for sustained support from NNI member agencies, the success of the NNI needs the insight and expertise of the stakeholder community (including, for example, academic researchers, industry representatives, and public citizens) as we continue to support research to build ***"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."***

Appendix A. External Assessment and Stakeholder Input

As referenced throughout this plan, a number of external sources provided the NNI with recommendations during the creation of this document. In contrast to the many public NNI-sponsored workshops held in 2008–2010 on a variety of general nanotechnology themes, the resources below targeted the development of this strategic plan in particular.

External Assessment Reports

"Report to the President and Congress on the Third Assessment of the National Nanotechnology Initiative" is available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nano-report.pdf

The President's Council of Advisors on Science and Technology performed the third assessment of the NNI, releasing its report on March 12, 2010. The report is largely supportive of the NNI and contains a number of specific recommendations which have been incorporated into this Plan, where possible.

"Review of Federal Strategy for Nanotechnology-Related Environmental, Health, and Safety Research" is available at http://www.nap.edu.

While the 2009 National Research Council's review document is mostly relevant to the NNI EHS Strategy, it did inform the drafting of some of the objectives in this strategic plan.

Stakeholder Input, July – August, 2010

To strengthen the development of this strategic plan, the NNI used a three-pronged approach to reach out to the nanotechnology stakeholder community for specific input. These activities occurred in July and August of 2010. The nanotechnology stakeholder community included those already familiar with the field of nanotechnology and the NNI, as well as those new to nanoscale science, engineering, and technology. Input was sought from a broad range of stakeholders, including members of the public; industry representatives; researchers in academic institutions; members of Federal, state, and local governments and regional initiatives; and representatives of nongovernmental organizations. The three stakeholder input activities were as follows:

- **Request for Information**

  A Request for Information (RFI) published in the Federal Register (Vol. 75, No. 128, Tuesday, July 6, 2010, pp. 38850–38853) referred to the NNI Goals as a starting point for questions covering themes of Goals and Objectives; Research Priorities; Investment; Coordination and Partnerships; Evaluation; and Policy. Submissions were accepted from July 6 – August 15, 2010. OSTP received 19 responses from individuals, industry representatives, academicians, state initiatives, and scientific societies.

- **NNI Strategy Portal: http://strategy.nano.gov**

  All stakeholders were invited to participate in the online public comment event hosted at the NNI Strategy Portal from July 13 –August 15, 2010. Once registered, community members were encouraged to post original responses and to comment on postings by other members. In the online event, participants were invited to post responses in four timed stages where the questions closely paralleled those posted in the RFI. At the closing of the online event on August 15, the NNI Strategy Portal community had almost 150 members. Although the period to respond to questions closed on August 15, 2010, the NNI Strategy Portal community continues to increase in membership, and it is seen as a potential mechanism for continuing to solicit public input in the future.

- **NNI Strategic Planning Stakeholder Workshop**

  From July 13–14, 2010, the NSET Subcommittee held a public workshop in Arlington, VA, to solicit input from the broad stakeholder community regarding the development of the NNI strategic plan. The workshop included plenary lectures where subject matter experts shared their insights and discussed the status of nanotechnology research and application areas. The hard work of the workshop occurred during the breakout sessions, where participants were asked to help the NSET Subcommittee formulate specific objectives under each of the four NNI goals.

The input from stakeholders in all three of these activities was invaluable in the development of the NNI Strategic Plan. Recommendations from the community have been carefully considered in creating the objectives found in this document. This plan does not make reference to specific R&D priorities beyond high-level areas such as nanomanufacturing. Furthermore, each of the NNI member agencies separately determine their budgets for nanotechnology R&D in support of their individual agency missions and needs, although to achieve the interagency budget crosscut, participating agencies work closely with each other through communication, collaboration, and coordination. The NNI will continue to use the stakeholder input regarding additional topics, such as R&D priorities and policy suggestions, to inform future decision making, as appropriate.

Some of the priorities, issues, and advice that the NNI received from stakeholders include the following:

- **R&D Priorities**

  Respondents identified a number of nanotechnology research priorities and concepts for future interagency Signature Initiatives, including quantum behavior, functional nanomaterials, photon-based computing, metamaterials, the nano-bio interface, tools for imaging and fabrication, process engineering, non-equilibrium systems, nanotechnology for low-cost sustainable energy, information needs, security, anticipatory governance, and nanotechnology pertaining to personal and public health (e.g., *in vitro* testing models, predictive toxicology, and high-throughput screening methods). The stakeholders were largely supportive of continuing and accelerating the NNI's efforts in nanomanufacturing, including the need for more research to increase the knowledge of fundamental processes and nanoscale phenomena.

- **Education and Workforce Development**

  Stakeholders emphasized the value of nanotechnology education as well as the critical need for a nanotechnology-trained workforce—including a recommendation to provide continuing education for patent examiners on the latest nanotechnologies.

- **Technology Transfer**

  Stakeholders provided examples of successful models for the transfer of technologies via state-led initiatives, "gap funding," and other technology transfer mechanisms. The need to foster collaboration between industry, the Federal Government, and researchers at universities was articulated by many stakeholders, as was the need for the Federal Government's sustained support for the development of voluntary consensus-based international documentary standards.

- **Improved Interagency Collaboration**

  Strategies recommended by stakeholders to improve NNI interagency activities included grand-challenge-themed pilot programs for interagency grant review boards involving program managers from various agencies, and grand-challenge-themed strategy teams with shared personnel from multiple agencies.

For further details, readers are directed to the online strategy portal (http://strategy.nano.gov) and the report from the NNI Strategic Planning Stakeholder Workshop (available at http://nano.gov).

Appendix B. Glossary

Act	The 21st Century Nanotechnology Research and Development Act of 2003
CNST	Center for Nanoscale Science and Technology (NIST)
CPSC	Consumer Product Safety Commission
DHS	Department of Homeland Security
DHHS	Department of Health and Human Services
DNI	Director of National Intelligence
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
EHS	environment(al), health, and safety
ELSI	ethical, legal, and social implications (of nanotechnology)
EOP	Executive Office of the President
EPA	Environmental Protection Agency
FDA	Food and Drug Administration (DHHS)
FHWA	Federal Highway Administration (DOT)
FS	Forest Service (USDA)
GAO	Government Accountability Office
GIN	Global Issues in Nanotechnology Working Group (NSET)
IC	Intelligence community
IP	intellectual property
nano-EHS	environment(al), health, and safety aspects of nanotechnology
NA	National Academies
NASA	National Aeronautics and Space Administration
NCI	National Cancer Institute (DHHS/NIH)
NEHI	Nanotechnology Environmental and Health Implications Working Group (NSET)
NIEHS	National Institute of Environmental Health Sciences (DHHS/NIH)
NIFA	National Institute of Food and Agriculture (USDA)
NIH	National Institutes of Health (DHHS)
NILI	Nanomanufacturing, Innovation, and Liaison with Industry Working Group (NSET)
NIOSH	National Institute for Occupational Safety and Health (DHHS/CDC)
NIST	National Institute of Standards and Technology (DOC)
NNAP	National Nanotechnology Advisory Panel (PCAST)
NNCO	National Nanotechnology Coordination Office
NNI	National Nanotechnology Initiative

NPEC	Nanotechnology Public Engagement and Communications Working Group (NSET)
NRC	National Research Council of the National Academies
NSET	Nanoscale Science, Engineering, and Technology Subcommittee of the NSTC Committee on Technology
NSF	National Science Foundation
NSRC	Nanoscale Science Research Centers (DOE program)
NSTC	National Science and Technology Council
OECD	Organisation for Economic Co-operation and Development
OMB	Office of Management and Budget (Executive Office of the President)
OSHA	Occupational Safety and Health Administration (DOL)
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
R&D	research and development
RFI	Request for Information
SBIR	Small Business Innovation Research program
STTR	Small Business Technology Transfer research program
USPTO	U.S. Patent and Trademark Office (DOC)
USDA	U.S. Department of Agriculture