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National Nanotechnology Investment in the FY 2008 Budget Request

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The emerging fields of nanoscale science, engineering, and technology —the ability to measure and restructure matter at the atomic and molecular levels to create materials, devices and systems with fundamentally new properties and functions—are leading to unprecedented understanding and control over the basic building blocks and properties of all natural and manmade things. The fiscal year (FY) 2008 funding request for nanoscale science, engineering and technology (in brief, *nanotechnology*) research and development (R&D) in 13 federal departments and agencies is $1.4 billion (see Table I-9). This investment is known as the National Nanotechnology Initiative (NNI) and began in FY 2001 with a budget of $494 million.[2] The NNI is a collaborative program among 26 federal departments and agencies with a long-term strategic plan to accelerate discovery, development and deployment of nanotechnology. [3] The budget increase is justified by the

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[2] See the NNI's website http://nano.gov

[3] Federal agencies with budgets dedicated to nanotechnology R&D are: U.S. Department of Agriculture, Cooperative State Research, Education, and Extension Service (USDA/CSREES); Forest Service (USDA/FS); Department of Defense (DOD); Department of Energy (DOE); Department of Homeland Security (DHS); Department of Justice (DOJ); Department of Transportation (DOT); Environmental Protection Agency (EPA); National Aeronautics and Space Administration (NASA); Department of Commerce, National Institute of Standards and Technology (DOC/NIST); Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (HHS/CDC/NIOSH); National Institutes of Health (HHS/NIH); and National Science Foundation (NSF). Other participating agencies are: Bureau of Industry and Security (DOC/BIS); Consumer Product Safety Commission (CPSC); Department of Education; Department of Labor (DOL); Department of State (DOS); Department of the

current results and potential to expand fundamental knowledge and contribute to national priorities such as economic competitiveness and public health. Because of the NNI, federal agencies have initiated major new nanotechnology R&D activities that support national goals and agency missions, there is an extensive and growing infrastructure of nanotechnology research and educations centers, and participating agencies are working together to maximize the effectiveness of their individual and collective investments.

The NNI vision is a future in which understanding and control of matter at the nanoscale will lead to a revolution in technology and industry. The four goals of the NNI are to: 1/ Maintain a world-class research and development program aimed at realizing the full potential of nanotechnology; 2/ Facilitate transfer of new technologies into products for economic growth, jobs, and other public benefit; 3/ Develop educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; and 4/ Support responsible development of nanotechnology.

The supported R&D is grouped into seven program component areas (PCAs) whose proposed FY 2008 funding levels are as follows: (1) Fundamental nanoscale phenomena and processes, $492 million for all NNI agencies in FY 2008; (2) Nanomaterials, $291 million; (3) Nanoscale devices and systems, $277 million; (4) Instrumentation research, metrology, and standards for nanotechnology, $84 million; (5) Nanomanufacturing, $44 million; (6) Major research facilities and instrumentation acquisition, $160 million; and (7) Societal dimensions, $96 million (including: environmental, health, and safety implications of nanotechnology development and risk assessment of such impacts, $59 million; education; and research on the ethical, legal, and social implications of nanotechnology, $41 million).

Funding generally is provided on a competitive basis with other programs and within NNI. The President signed on December 3, 2004, the "21st Century Nanotechnology R&D Act" (Public Law 108-153). This Act recommend funding levels for five agencies—NSF, DOE, NASA, NIST and EPA—for fiscal years 2004-2008. NSET published its

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Treasury; Food and Drug Administration (HHS/FDA); International Trade Commission (ITC); Intelligence Technology Innovation Center (ITIC); Nuclear Regulatory Commission (NRC); Technology Administration (DOC/TA); U.S. Geological Survey (USGS); U.S. Patent and Trademark Office (DOC/USPTO).

long-term strategic plan beginning with FY 2006 on December 2004.[4] The President's Council of Advisors on Science and Technology (PCAST), which was assigned as the National Nanotechnology Advisory Panel (NNAP) called for by the Act, reviewed NNI in the report "NNI at Five Years (2005)." The National Research Council published two reviews of NNI, in 2002 and 2006. Nanotechnology is highlighted by the American Competitiveness Initiative which provides support to NSF, DOE (Office of Science) and NIST.

SUMMARY FOR ALL AGENCIES

Priorities in FY 2008: The FY 2008 President's request of $1.4 billion for federal investment in nanoscale science provides a 3.8 percent increase over the current FY 2007 estimate. The FY 2008 increases are at NSF, DOE, NIH, NIST, EPA and USDA. The budget decreases at DOD and NASA may be explained by the reassignment of applied nanotechnology projects to other areas of relevance, as well as by the overall budget constrains in FY 2008. Approximately 65 percent of total NNI funding supports academic research. The balance funds R&D at government laboratories (about 25 percent) and in industry (about 10 percent to industry, of which 7 percent is small business).

The initiative focuses on long-term research to understand the manipulation of matter at the atomic and molecular levels. Applications areas include electronics for information technology; high-performance, lower-maintenance materials and design for manufacturing, defense, transportation, space, and the environment; applications in medicine, health care, and agriculture; and extending the limits of sustainable development. In FY 2008**,** priority in R&D funding will be given to research on: (1) advancing the knowledge frontiers of nanoscale phenomena and processes to extend systematic control over matter at the nanoscale, and in particular to quantum phenomena and self-assembling processes; (2) materials with emerging behavior, including activities related to the hydrogen economy; (3) active nanostructures and complex nanosystems; (4) enabling the design of hierarchically structured materials and efficient nanomanufacturing from the molecular scale; (5) nano-biosystems and medicine; (6) silicon nanoelectronics and beyond; (7) development of instrumentation, metrology and standards; and (8) environmental, health and safety (EHS) issues with a $59 million or 55 percent increase over FY 2006 actual budget. It will also support: (1) the

[4] The NNI Strategic Plan, NSET, Washington, D.C., December 2004

education and training of the new generation or workers for the future industries; (2) research to address ethical and other social issues raised by the development of nanotechnology; (3) major scientific user facilities with advanced instrumentation; and (4) partnerships to enhance industrial participation in the nanotechnology revolution. The convergence of nanotechnology with information technology, modern biology and social sciences will reinvigorate discoveries and innovation in almost all areas of the economy.

Key areas of growth are nanotechnology research for nanomedicine (particularly at NIH), nanoscale systems and their manufacturing (particularly at NSF and NIST), energy conversion (particularly at DOE and NSF), agriculture and forestry products (at USDA), and EHS (particularly at EPA, NIOSH, NIH, DOE and NSF). The detailed NNI priorities per PCA and agency are presented elsewhere.[5] The Department of Education and Department of Labor have become NNI participants.

***Collaborative activities*:** The National Science and Technology Council (NSTC) Subcommittee on Nanoscale Science, Engineering and Technology (NSET) will coordinate joint activities that create synergies between the individual agencies in a variety of topics and modalities of collaboration. NSET will identify the most promising research directions; fund complementary/synergistic fields of research that are critical for the advancement of the nanoscience and engineering field; develop a balanced infrastructure (portfolio of programs, development of new specific tools, instrumentation, simulation infrastructure, standards for nanoscale); correlate funding activities for centers and networks of excellence; cost-share high cost R&D activities; develop a broad workforce trained in the many aspects necessary to nanotechnology; study the diverse, complex implications on society such as the effect of nanostructured material manufacturing on the environment and the effect of nanodevices on health; and avoid unnecessary duplication of efforts. NSET will also address NNI management issues, the interaction with nanotechnology regional alliances, and international activities.

Several NSET working groups (Nanomaterials Environmental and Health Implications, Nanotechnology Industrial Liaison and Innovation, Nanomanufacturing, Nanotechnology Public Engagement, and Global Issues in Nanotechnology) provide support for partnerships.

[5] Details are in NNI Supplement to the President's FY 2008 Budget, Washington, D.C., est. March 2007.

Examples of specific coordination efforts are:

- National Nanomanufacturing Network (key partners NSF, DOD, and NIST; the main node of the network is at University of Massachusetts, Amherst);
- Environmental and health issues (two joint solicitations are planned involving EPA, NIOSH, NIH, NSF, DOE and USDA, and a partnership with European Community is explored in FY 2008; NIH, FDA and NIOSH continue to collaborate in the National Toxicology Program that involves the toxicological evaluation of specific engineered nanomaterials;
- NIH, FDA and NIOSH continue to collaborate in support of the Nanotechnology Characterization Laboratory (NCL) established by the National Cancer Institute);
- Infrastructure development (such as among R&D centers - NSECs, NNIN, NCN, and centers and networks with DOE, DOD, NASA, NIH, and NIST);
- Particle characterization and standards development (NIST, FDA, NIH, NSF and other agencies); Modeling and simulation and nanoelectronics (DOD, DOE-Sandia National Laboratory, NASA and NSF);
- Collaborating with the Semiconductor Research Corporation to develop the next generation of nanometer-scale lithography technology (NSF and DOD); Cooperative efforts between DOD (ARO) and DOE (Sandia National Laboratory) to develop monolithic absorber/bolometric sensors for terahertz detectors;
- Interdisciplinary research at the intersection of nanotechnology, biotechnology and information technology (NSF, NASA, EPA). Cooperative efforts between DOD, DOE, NASA, and NSF on materials, and device development and modeling for direct thermal-to-electrical energy conversion will be undertaken in areas of thermoelectric, thermophotovoltaics, and thermionics.
- DOE, NSF, NIH, and NIST will collaborate on development and use of neutron and synchrotron facilities.
- NIH (NCI) and NIST will collaborate on nanobiotechnology, including novel opto-immunoassays for probing the molecular pathology of prostate cancer.
- DOD collaborates with NSF in the NSF-Navy Civilian Service Fellowship/Scholarship program.
- NIH and NSF are actively exploring ways to expand the scope of the institutional NCI-NSF Integrative Graduate Education and

Research Traineeships (IGERT) awards initiated in FY 2005 in support of nanobiotechnology training.

NATIONAL SCIENCE FOUNDATION (NSF)

The FY 2008 request is $389.9 million, a $16.7 million increase over the FY 2007 current estimate (see Table 1).

Table 1. NSF Directorate Budgets for NNI Funding
(in millions of dollars)

NSF Directorate	FY 2006 Actual	FY 2007 Request	FY 2008 Request	Change over FY 2007 Amount	Percent
Biological Sciences	49.00	52.55	55.55	3.00	5.7%
Computer and Info. Sci.	10.42	12.87	11.00	-1.87	-14.5%
Engineering	127.77	137.02	139.02	2.00	1.5%
Geosciences	9.00	9.65	9.65	0.00	0.0%
Mathematical and Phys. Sci.	158.24	156.42	169.91	13.49	8.6%
Social, Behavioral and Econ.	1.56	1.67	1.67	0	0.0%
Office of Intl Sci. and Eng.	0.48	0	0	0	--
Subtotal, R&RA	356.47	370.18	386.80	16.62	4.5%
Education and Human Res.	3.24	3.00	3.10	0.10	3.3%
Total NNI @ NSF	$359.71	$373.18	$389.90	$16.72	4.5%

The Nanoscale Science and Engineering (NSE) Group coordinates NNI activities at NSF. The NSF investment will be expanded to develop and strengthen critical field and to establish the science and engineering infrastructure and workforce needed to exploit the opportunities presented by new capabilities. NSF supports fundamental knowledge creation across all disciplinary areas at the nanoscale. FY 2008 support includes centers ($50 million).

The national outreach of the eight nanotechnology research and education networks listed in Table 2 will be focused on:

- Infrastructure: National Nanotechnology Infrastructure Network (13 sites for user facilities) and Network for Computational Nanotechnology (7 sites for research and user facilities) will serve about 16,000 academic and industry users at their facilities;

- Four priority areas: Nanotechnology in Society Network (4 main sites), Nanoscale Center for Learning and Teaching, Nanoscale Informal Science Education (3 main sites), and National Nanomanufacturing Network (4 main academic sites),

- General research and education: Nanoscale Science and Engineering Centers; Material Research Science and Engineering Centers.

- A new network with a main center on environmental health and safety with an annual budget of about $3 million will be established in 2008.

These networks will establish a research and education platform for nanotechnology at the national level. This will include open and remote access to projects that were selected based on merit review. This will also serve as national clearinghouses for information. Based on their history, these nine networks will provide support for industry partnerships with over 100 companies in FY 2008. The Major Research Instrumentation Program and other programs will continue to support the creation of smaller academic nanoscale science and engineering facilities.

An increased investment will be dedicated to research and education on:

- The use of quantum phenomena in nanoscale devices and self-assembling processes at various length scales,

- Active nanostructures, systems of nanosystems and molecular nanosystems. Research on nanoscale devices and system architecture, and their respective fabrication, will be emphasized;

- Converging science, engineering and technology from the nanoscale, and in particular at the nano-biology interface and nano-information interface;

- Nanotechnology for water filtration and energy conversion.

- Long-term societal implications of nanotechnology in society, and public interaction; and

- Programs and teaching materials supporting early educational experience related to nanotechnology, including K-12.

Long-term objectives include laying a foundation of fundamental research for NNI mission-oriented agencies and industry; ensuring that U.S. institutions will have access to a full range of nano-facilities; enabling access to nanotechnology education for students in U.S. colleges and universities; and catalyzing the creation of new commercial markets that depend on three-dimensional nanostructures. This should result in the development of completely new technologies that contribute to improvements in health, advanced agriculture, conservation of materials and energy, and sustainability of the environment. This investment will be expanded in FY 2008 to develop and strengthen critical fields and to establish the science and engineering infrastructure and workforce needed to exploit the opportunities presented by these new capabilities, including nanoelectronics and nanobiotechnology.

NSF's planned investment for Nanoscale Science and Engineering in FY 2008 will contribute to all NNI program component areas. The largest contribution will be to "Fundamental nanoscale phenomena and processes" ($142.7 million).

The FY 2008 Request includes $62.9 million for societal dimensions, an increase of $3.9 million over the FY 2007 request, for various research and other activities that address the broad implications of nanotechnology for society, including benefits and risks, such as:

- Research directed at environmental, health, and safety impacts of nanotechnology development and basic research supporting risk assessment of such impacts ($28.8 million). Research will address various sources of nanoparticles and nanostructured materials in the environment (in air, water, soil, biosystems, and the working environment), as well as biological implications (non-clinical research). New measurement methods for nanoparticle characterization and toxicity of nanomaterials will be investigated.

- Education-related activities, such as the development of materials for schools, curriculum development for nanoscience and engineering, development of new teaching tools,

undergraduate programs, technical training, and public outreach ($28.3 million).

- Research directed at identifying and quantifying the broad implications of nanotechnology for ethical, legal, and other social issues, ELSI ($5.8 million). The application of nanoscale technologies will stimulate far-reaching changes in the design, production, and use of many goods and services. Factors that stimulate scientific discovery at the nanoscale will be investigated, effective approaches to ensure the safe and responsible development of nanotechnology will be explored and developed, and the potential for converging technologies to improve human performance will be addressed.

DEPARTMENT OF DEFENSE (DOD)

The FY 2008 request is $374.7 million, $43 million less than the FY 2007 estimate in the current plan which includes congressionally directed funds (see Table I-9). Since DOD is a mission-oriented agency, its nanotechnology programs are simultaneously focused on scientific and technical merit and potential relevance to DOD. The overall objective for DOD is to discover and exploit unique phenomena at material structures in the range of 1 to 100 nanometers to enable novel applications enhancing war fighter and battle systems capabilities. The principal DOD participants in the NNI are the Directorate for Defense Research and Engineering (DDR&E), the Defense Advanced Research Projects Agency (DARPA), the Air Force, the Army and the Navy. The Defense Threat Reduction Agency (DTRA), the U.S. Army Medical Research and Materiel Command and the DOD Manufacturing Technology (MANTECH) program are evaluating nanotechnology as an investment area. DOD supports nanoscale science and technology in order to meet the national security mission.

Within DTRA, a new nanotechnology program in chem/bio/info/cogno defense has been initiated. New DARPA programs exploiting nanotechnologies are expected in 2008; specific topics have yet to be identified, but those under development will emphasize the application of nanotechnology in applications relevant to national defense, such as quantum computation and nanoelectronic devices. DOD will play a major role in the multiagency effort on miniaturized sensors for chemical, biological, radiological and explosive (CBRE) agents, for

nanostructures enabling protection against agents, and for nanostructures that neutralize agents. DOD will provide advanced nanoscience instrumentation via the Defense University Research Instrumentation Program (DURIP).

DEPARTMENT OF ENERGY (DOE)

In FY 2008, the total request is $331.5 million, a $38.2 million increase over the FY 2007 estimate (see Table I-9). The FY 2008 request includes a substantial increase in funding for research at the nanoscale for activities related to the hydrogen economy, solar energy conversion, fundamental studies of materials at the nanoscale, instrumentation for characterizing materials at the nanoscale, and research relevant to environmental and ecological aspects of nanomaterials. In addition, the FY 2007 request includes a large investment for all five Nanoscale Science Research Centers (NSRC), which will be fully operational in 2008. Support for fundamental scientific research on nanoscale phenomena will be by grant programs and DOE National Laboratory research efforts. Research will include surface and interfacial chemical phenomena; catalysis; nanoparticle reactivity; photochemistry at the nanoscale; electronic, optical, magnetic, thermal, mechanical, and other materials properties; nanoscale organic-inorganic hybrids and interfaces; theory, modeling, and simulation; advanced scientific computing; and investigation of principles of assembly and positional control of nanoscale objects (such as nanoparticles, nanotubes, nanowires, quantum dots, etc.) to create devices, arrays, or systems via self-assembly, templated assembly, and biologically assisted assembly. Increased effort will be devoted to research on novel X-ray, electron, and other scattering phenomena to investigate dynamic and ultrafast processes at the nanoscale.

In addition, nearly $46 million of the FY 2008 DOE request will support investments by the Office of Energy Efficiency and Renewable Energy, mostly in the area of nanomaterials research.

DOE will continue development of a transmission electron aberration-corrected microscope (TEAM)—an instrument taking advantage of recent advancements in correction of electromagnetic lens defects to reach previously unobtainable performance levels. TEAM is a multi-year project involving five DOE-supported electron scattering research groups, with substantial involvement of equipment manufacturers to

develop a next-generation electron microscopy platform. New beam line instrumentation will be employed at neutron scattering centers and synchrotrons to facilitate investigation of nanostructures. Modular micro-laboratories for collaborative work will be developed at the DOE NSRCs, such as the Center for Integrated Nanotechnologies' "discovery platforms," and other R&D activities on nanomanufacturing processes.

DOE's Office of Biological and Environmental Research will expand its support for activities related to ethical, legal and societal issues of nanotechnology in FY 2008. New funds are requested for research on environmental and ecological implications of nanomaterials that could find application in energy technologies.

HHS: NATIONAL INSTITUTES OF HEALTH (NIH) AND NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)

The total FY 2008 request by HHS is $207.5 million, which would support nanotechnology activities in NIH and NIOSH.

The FY 2008 NIH request is $202.9 million, $32.7 million over the 2007 estimate. NIH has several roadmap initiatives.[6] NIH's priority for nanotechnology research continues to be creating novel diagnostic and therapeutic approaches and devices, and operating research capabilities to understand fundamental biomedical mechanisms. A consortium of 17 NIH institutes re-released the solicitation, Nanoscience and Nanotechnology for Biology and Medicine, both for regular research grants and feasibility projects. Large centers and related programs at the National Cancer Institute (NCI), National Heart, Lung, and Blood Institute (NHLBI), and Nanomedicine Roadmap Initiative will continue in 2008. The National Institute of Dental and Craniofacial Research (NIDCR) issued in 2006 a request for applications (RFA) to encourage research leading to the development of nanostructured dental composite materials.

There is a continued ramp-up of nanotechnology R&D funding for programs including implementing the Nanomedicine Roadmap Initiative, NCI's Nanotechnology Platform Partnerships and Nanotechnology Characterization Laboratory, the NHLBI's Programs of Excellence in Nanotechnology, and the Nanotechnology Program Area at the National Institute of Biomedical Imaging and Bioengineering.

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

NIH will continue to support the development of: new nanoscale devices and systems for the early and specific detection of disease before pathology has substantially damaged the body; treatment of disease by use of directed methods that reduce undesired side-effects; monitoring of treatment efficacy; and repair of tissue that is damaged due to inborn conditions and trauma (*e.g.*, accidents, disease, environment, battlefield trauma). Studies of biocompatibility are integral to many NIH-supported studies. For example, research to develop new nanotechnology-based imaging agents or restorative implants routinely include animal studies on the distribution, processing and excretion of these materials, and monitoring for adverse effects that may occur during and after treatment.

Under the Nanomedicine Roadmap Initiative, NIH is completing a network of nanotechnology research centers in FY 2008. An NIH-wide Nanotechnology Task Force will coordinated nanotechnology related investments.

Other NIH programs include: (a) the National Institute of General Medical Sciences (NIGMS) program area entitled, "Single Molecule Biophysics and Nanoscience," (b) a portion of the NHLBI and NCI nanotechnology programs (with the majority of funding under the PCA on Nanoscale Devices and Systems); (c) a portion of the NCI's Integrative Cancer Biology program; and (d) a portion of the National Human Genome Research Institute (NHGRI) program to develop novel DNA sequencing technologies. This will involve additional work under the PCA on Nanoscale Devices and Systems that will develop new fundamental knowledge needed to support device development, and (e) several projects under the NIH Roadmap Initiative on Molecular Libraries and Imaging to develop fundamental new approaches for molecular imaging in biological systems.

At NCI, the Alliance for Nanotechnology in Cancer (nano.cancer.gov) funded eight Centers of Cancer Nanotechnology Excellence (CCNEs) to serve as hubs to develop and apply nanotechnology devices and systems to the diagnosis, prevention, and treatment of cancer. The NCI Alliance also awarded multidisciplinary cancer nanotechnology fellowships and twelve cancer nanotechnology platform development partnerships. These Alliance program activities are fully integrated with existing NCI programs and resources.

At NHGRI, the "$1,000 Genome" program, initiated in 2004, expanded in 2005, and continuing through 2007, explores the development of nanosensors the size of individual DNA molecules for the rapid, inexpensive sequencing of DNA, for use in medicine, sensors, etc.

At the NHLBI, Programs of Excellence in Nanotechnology seek to apply nanotechnology to the diagnosis and treatment of heart, lung, blood, and sleep diseases. Another program goal is to train a cadre of investigators with the skills required to apply nanotechnology to this research.

At the National Institute of Neurological Disease and Stroke (NINDS), programs support research to reduce the burden of neurological disease by investigating nanotechnology as a tool to study the development, structure and function of the brain. Nanoscale devices will be used for in vivo imaging and drug delivery, with utility for clinical assessment, diagnosis, and treatment of disorders of the nervous system.

NIH provides critical infrastructure and characterization services to nanomaterial providers in order to accelerate the transition of basic nanoscale particles and devices into clinical applications, thereby reducing suffering and death from cancer. NCI's Nanotechnology Characterization Laboratory will serve as a national resource and knowledge base for all cancer researchers to facilitate the regulatory review of nanotechnologies intended for cancer therapies and diagnostics.

SBIR and STTR programs for 2008 include:

• Nanomedicine Roadmap, NIH-wide
• Programs of Excellence in Nanotechnology, NHLBI
• Alliance for Nanotechnology in Cancer, NCI
• NTP program on Toxicological Evaluation of Nanoscale Materials

The FY 2008 NIOSH request is $4.6 million, unchanged from the previous year. The Institute will operate the Center of Excellence for Nanotechnology Research, with the role of coordinating nanotechnology-related activities across the institute and addressing critical occupational health issues. NIOSH will continue to develop partnerships with stakeholders and other organizations to enable the translation of agency activities into appropriate workplace practices. NIOSH will establish a suite of instruments and protocols for

characterizing nanomaterials in the workplace environment. This budget will allow intramural and extramural projects targeted to addressing critical research gaps around occupational safety and health of nanotechnology and nanomaterials.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

The FY 2008, NASA request for nanotechnology programs is approximately $24 million, a decrease of $1 million from the FY 2007 estimate (see Table I-9). The budget reflects the competition with other NASA priorities. In addition to basic nanoscience and nanotechnology research, NASA plans to invest in various application areas. The basic NASA nanoscience program includes bio-molecular systems research, which is a joint NASA/NCI initiative. The Office of Advanced Technology Program integrates nanotechnology development in three areas: (1) Materials and structures, (2) Nanoelectronics and computing, and (3) Sensors and spacecraft components. A major focus at NASA is to advance and exploit the zone of convergence between nanotechnology, biotechnology, and information technology. Areas to be emphasized include: ultrahigh strength and multi-functional materials; high density, low power electronics; ultra-small and sensitive sensors; and highly miniaturized spacecraft systems (from microelectromechanical systems (MEMS) to nanoelectromechanical systems (NEMS)).

A focus of NASA research will be at the intersection of biology and nanotechnology to develop: (a) a bio-analytical laboratory for interrogating extraterrestrial samples, (b) high-density transducer arrays for providing high throughput, quantitative physiological monitoring for astronauts, and (c) diagnostic technologies for spaceship environmental monitoring.

Another focus will be on nanomaterials with properties desired for future space systems, including large size per mass (for ultra-large apertures, solar sails, etc.) and high strength per mass (for launch vehicles, human habitats in space, etc.).

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

The FY 2008 NIST request is $96.6 million, a $7.3 million increase from the FY 2007 estimate (see Table I-9). The Center for Nanoscale Science and Technology (CNST, Gaithersburg campus) will focus on

collaborative nanotechnology research on cost-effective manufacturing of products made with components the size of atoms and molecules. Additional foci at NIST include the development of standard reference materials for nanotechnology and research related to nanomanufacturing.

Projects in the following areas will be funded: molecular electronics, quantum computing, nanomagnetodynamics, nanotribology, and autonomous atom assembly. Approximately half of the total allocated funds will be used to continue current internal efforts in several of these areas, and half will be used to leverage existing efforts with external partners. The funds are distributed, using a competitive process, across the NIST Laboratories for enabling infrastructural measurement, standards, and data for nanomagnetics, nanocharacterization, chemical characterization, and new information technologies. Developing the theoretical underpinnings needed to enable the engineering of practical quantum computing devices will be pursued. A goal is advancing innovation and application of nanomaterials across all technology sectors.

Nanomanufacturing and nanofabrication programs will be enhanced in nanoimprint lithography, particle metrology and other manufacturing metrology techniques. These programs also support development and delivery of measurement and infrastructural technologies to provide traceable metrology, process control, and quality assurance for nanoscale manufacturing. Funding would also be increased for research on measurements of nanomechanical properties and on nanotube/nanoparticle metrology, and for efforts to produce nanoelectronics and nanophotonics devices.

The National Nanomanufacturing and Nanometrology Facility (N^3F) opened in Gaithersburg, MD, in 2005. The N^3F was developed at NIST to support the development of new infrastructural metrology and standards for U.S. nanotechnology efforts through centralized access to NIST's nanometrology and nanofabrication resources, including the facilities of the Advanced Measurement Laboratory and NIST's nanometrology experts. Several new programs are developing physical standards and measurement methods for nanoparticles and accelerating their use in new classes of materials, as well as assessing environmental impact.

NIST in collaboration with the University of Minnesota and the Virginia Military Institute will continue work on full-scale drinking water facilities using a coagulation-flocculation process specifically designed if carbon nanotubes would be present.

NIST will develop stronger strategic alliances and collaborations with universities, businesses, and other government agencies that possess leading expertise in nanotechnology. NIST plans to direct half of the new nanotechnology funding to these external organizations to conduct much of the specific work required to meet the goals of this initiative and to avoid developing costly, complex in-house capabilities that may only be used once. NIST has a large range of collaborations with industry.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The FY 2008 request is $10.2 million, a $1.6 million increase from the FY 2007 estimate (see Table I-9). The agency is expanding its research program on potential environmental implications of nanotechnology. In line with EPA's Nanotechnology White Paper that was published on February 16, 2007, this program includes intramural research within EPA's Office of Research and Development, as well as the extramural program that has been in place for several years. EPA has launched a collaborative process to design a Nanoscale Materials Stewardship Program for voluntary reporting of nanomaterials production under the provisions of the Toxic Substances Control Act (TSCA).

EPA's research is organized around the risk assessment/risk management paradigm. Research on human health and environmental effects, exposure, and risk assessment is combined to inform decisions on risk management. Research on environmental applications and implications of nanotechnology can be addressed within this framework. Nanotechnology may offer the promise of improved characterization of environmental problems, significantly reduced environmental impacts from "cleaner" manufacturing approaches, and reduced material and energy use. The potential impacts of nanoparticles from different applications on human health and the environment will be a focus area.

EPA will continue to focus the majority of its research in 2008, as in 2007, on health and environmental implications of nanomaterials. EPA will increase its efforts in the area of risk assessment and risk

management needs for nanomaterials. Finally, EPA will research nanoscale technology as potential solutions to environmental problems.

FOOD AND DRUG ADMINISTRATION (FDA)

FDA will be addressing scientific and policy concerns and issues related to nanotechnology use for the entire spectrum of FDA-regulated products under the auspices of the recently established FDA Nanotechnology Task Force and Nanotechnology Interest Group (NTIG), which is comprised of scientists qualified to provide input on product development. Under a tripartite MOU, FDA, NIH (NCI) and NIST have agreed to collaborate, share know-how and data on particle characterization and standards development.

U.S. DEPARTMENT OF AGRICULTURE (USDA: CSREES AND FS)

The FY 2008 request is approximately $7.6 million ($3 million for CSREES and $4.6 million for FS), about $2 million over the FY 2007 esimate. USDA conducts its research both extramurally through the partnership between CSREES, the Land Grant Universities (LGUs) and SBIR, and in-house at Agriculture Research Service (ARS) national laboratories. The CSREES also provides leadership and financial support for education and outreach in all the states and territories of the United States through the LGUs.

The USDA nanotechnology program will continue in 2008 through its Nanotechnology Research Initiative for extramural competitive research and education grants. R&D efforts will contribute to the NNI program component areas, with a central theme of exploiting the novel properties of nanoscale biological structures derived from important agricultural materials. The development of nanotechnology-based sensors for application in the food industry and agriculture is also a priority, and will similarly expand. Other areas of focus are research on: nanoscale phenomena and processes with significant implications for improving biological production, processing, and preservation; sensors to ensure food safety and biosecurity, preserve and track product identity, improve environmental quality, enhance production and process efficiency; research for promoting optimal human health through novel delivery mechanisms of bioactive ingredients in foods.

The Forest Service will focus on applications of nanotechnology to enhanced utilization of forest resources and research on low-cost forest product feedstocks for nanomanufacturing. The USDA Forest Service will carry research to determine the basic nanoscale cell wall architecture of wood and bark, wood-binder interaction, utilization of nano-carbon materials recovered from gasification of woody biomass, as well as characterization of nanoscale structures of chemically and physically altered wood fiber cell wall surfaces. Additional research includes utilization of nano-carbon particles recovered from woody biomass gasification and cellulose nanocrystals isolated from wood to reinforce structural wood-based composites.

DEPARTMENT OF JUSTICE (DOJ)

In FY 2008 the budget request for the DOJ is about $1 million. The DOJ National Institute of Justice (NIJ) has two separate project areas that incorporate nanotechnology—DNA Research and Development, and Chemical and Biological Defense. The DNA Research and Development program will continue basic research as well as the demonstration of chip-based or micro-device technologies to analyze DNA in forensic applications. Nanotechnology has or will be a significant part of the device under development that will eventually be integrated into the current crime laboratory processes and protocols to analyze forensic DNA samples. The Chemical and Biological Defense program is developing a wearable, low-cost device to provide warning of exposure to unanticipated chemical and biological hazards in sufficient time for its wearer to take effective protective measures. The current approach relies on an enzymatic reaction. It is based on vapor exposure of an immobilized enzyme surface. Evolving nanotechnology may be used to address limitations of the enzymatic approach.

US DEPARTMENT OF TRANSPORTATION (DOT: FHWA)

The Federal Highway Administration budget of $0.9 million in FY 2008 is supporting research aimed at improving fundamental understanding of the structure and properties of highway construction materials at the nanoscale, e.g., the use of atomic force microscopy to characterize the morphology of asphaltenes, which are the nanoparticle component of asphalt. The FHWA, in collaboration with the University of Connecticut and W.R. Grace, Inc., and with support from an NSF grant will

investigate the nanoscale mechanisms controlling hydration and setting of Portland cement concrete.

Table 2. Key NNI R&D user facilities and networks

Center Name	Institution
NSF – eight networks	
National Nanofabrication Infrastructure Network (NNIN) – 13 nodes (user facilities)	Cornell University –central node
Network for Computational Nanotechnology (NCN) – 7 nodes (user facilities)	Purdue University – central node
National Nanomanufacturing Network (NNN)	University of Mass., Amherst – central node
Nanotechnology in Society Network (NCN)	ASU – central node
Nanoscale Center for Learning and Teaching (NCLT)	Northwestern University –main node
Nanoscale Informal Science Education (NISE)	Museum of Science Boston - main node
Nanoscale Science and Engineering Centers (NSEC)	University of Columbia- main node
Materials Science and Engineering Centers (MRSECs)	Distributed
DOE – one network of five user facilities	
Center for Functional Nanomaterials	Brookhaven National Laboratory
Center for Integrated Nanotechnologies	Sandia NL and Los Almos NL
Center for Nanophase Materials Sciences	Oak Ridge National Laboratory
Center for Nanoscale Materials	Argonne National Laboratory
Center for Molecular Foundry	Lawrence Berkeley National Laboratory
NIH - four networks	
NHLBI Program of Excellence in Nanotechnology	Four centers
Nanomedicine Development Centers	Eight centers
Centers of Cancer Nanotechnology Excellence	Eight centers
Nanotechnology Characterization Laboratory (user facilities)	NCI Frederick
NIST – one user facility	
Center for Nanoscale Science and Technology	NIST Gaithersburg
NSF	
National Nanofabrication Infrastructure Network (NNIN) – 13 nodes	Cornell University –central node
Network for Computational Nanotechnology (NCN) – 7 nodes	Purdue University – central node
DOE	
Center for Functional Nanomaterials	Brookhaven National Laboratory
Center for Integrated Nanotechnologies	Sandia NL and Los Almos NL
Center for Nanophase Materials Sciences	Oak Ridge National Laboratory
Center for Nanoscale Materials	Argonne National Laboratory
Molecular Foundry	Lawrence Berkeley National Laboratory