24

National Nanotechnology Investment in the FY 2007 Budget Request

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The emerging fields of nanoscale science, engineering, and technology —the ability to work at the atomic and molecular levels to create large structures 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) 2007 funding request for nanoscale science, engineering and technology (in brief, *nanotechnology*) research and development (R&D) in twelve federal departments and independent agencies is summarized in Table I-9. This investment is known as the National Nanotechnology Initiative (NNI) and began in FY 2001.[2] The NNI is a collaborative program among 25 federal agencies with a long-term strategic plan. Because of the NNI, 1) federal agencies have initiated major new nanotechnology R&D activities that support national goals and agency missions; 2) there is an extensive and growing infrastructure of nanotechnology research and educations centers; 3) the 25 participating agencies are working together to maximize the effectiveness of their individual and collective investments through communication, coordination, and joint planning and programs.

The vision of the NNI is a future in which the ability to understand and control matter on the nanoscale leads to a revolution in technology and industry. The four goals of the NNI are: 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

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

infrastructure and tools to advance nanotechnology; and 4/ Responsible development of nanotechnology.

The supported R&D is grouped in seven program component areas (PCAs): (1) Fundamental nanoscale phenomena and processes; (2) Nanomaterials; (3) Nanoscale devices and systems; (4) Instrumentation research, metrology, and standards for nanotechnology; (5) Nanomanufacturing; (6) Major research facilities and instrumentation acquisition; and (7) Societal dimensions (including: environmental, health, and safety implications of nanotechnology development and risk assessment of such impacts; education; and research on the ethical, legal, and social implications of nanotechnology).

Funding generally is provided on competitive basis with other programs and within NNI. The Congress approved in November 2003 and the President signed on December 3, 2004, the "21st Century Nanotechnology R&D Act" (Public Law 108-153) with funding recommendations for five agencies (NSF, DOE, NASA, NIST and EPA) for fiscal years 2004-2008 and beyond. NSET has published its long-term strategic plan beginning with FY 2006 on December 2004.[3] The President's Council of Advisors on Science and Technology (PCAST) was assigned as the National Nanotechnology Advisory Panel (NNAP) called by the Act indicated above, and reviewed NNI in the report "NNI at Five Years."

SUMMARY FOR ALL AGENCIES

Priorities in FY 2007: The FY 2007 President's request (published in February 2006) of $1,277 million for federal investment in nanoscale science, engineering and technology is an increase of 21 percent over the FY 2006 request, but is smaller than the estimated expenditure in FY 2006 of about $1.3 billion that includes congressionally directed investments (see Table I-9). The FY 2007 budget increases are at the National Science Foundation (NSF), the Department of Energy (DOE), the National Institute of Standards and Technology (NIST), the Environmental Protection Agency (EPA) and the U.S. Department og Agriculture (USDA). The budget decreases in the same request at Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA) may be explained by the reassignment of applied nanotechnology projects to the respective areas of relevance, and

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

congressionally directed funding for nanotechnology in FY 2005 and FY 2006, as well as by the overall budget constrains in FY 2007. Roughly 65 percent of the funding proposed under the NNI supports academic research, about 25 percent to government R&D laboratories, and 10 percent to industry (where small businesses is about 7 percent).

The initiative focuses on long-term research on understanding the manipulation of matter at the atomic and molecular levels, leading to an unprecedented ability to create nanostructured materials and systems for advanced products such as new classes of devices as small as molecules and machines as small as human cells. Applications areas include continued improvement in electronics for information technology; higher-performance, lower-maintenance materials and design for manufacturing, defense, transportation, space, and environment; accelerated, biotechnical applications in medicine, health care, and agriculture; and extending the limits of sustainable development. In FY 2007, priority in R&D funding will be given to: (1) advance the knowledge frontiers of nanoscale phenomena and processes to an extend that systematic control over matter at the nanoscale could be achieved; (2) materials with emerging behavior; (3) increased research focus on active nanostructures and complex nanosystems; (4) research to enable 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; (8) environmental, health and safety issues, including development of instrumentation for environmental and toxicity studies; (9) the education and training of the new generation or workers for the future industries; (10) addressing ethical and other social issues raised by the development of nanotechnology; (11) establish and operate major scientific user facilities with advanced instrumentation; and (12) 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. Areas of growth are nanotechnology research for nanomedicine, nanoscale systems and their manufacturing, energy conversion, agriculture and forestry products. The detailed NNI priorities per PCA and agency are under evaluation following as series of

NSET sponsored workshops.[4] 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. The coordination 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. The coordination also will address NNI management issues, interaction with nanotechnology regional alliances, and international activities. The National Nanotechnology Coordinating office (NNCO) is the secretarial office of NSET for this purpose. 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. Examples of specific coordination efforts are: Nanomanufacturing (main partners NSF, DOD, and NIST); Environmental issues (EPA, NIOSH, NSF, and USDA); Infrastructure development (such as among R&D centers -NSECs, NNIN, NCN, and centers and networks with DOE, DOD, NASA, NIH, and NIST); Standards development (NIST, all 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; and Interdisciplinary research at the intersection of nanotechnology, biotechnology and information technology (NSF, NASA, EPA).

[4] Details are in *NNI Supplement to the President's FY 2007 Budget*, Washington, D.C., April 2006.

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. FDA, NIH (NIEHS), and NIOSH will continue their partnership to manage and operate the National Toxicology Program's Nanotechnology Safety Initiative that involves the toxicological evaluations of specific engineered nanoscale materials. This program seeks students at the bachelor's, master's, or doctoral level in science, technology, engineering, and mathematics who wish to commit a portion of their careers to serve at a Navy R&D center.[5] 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 2007 request is $373 million, $29.4 million over FY 2006 (see Table 1).

The Nanoscale Science and Engineering (NSE) Group coordinates the 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. Support will be focused on interdisciplinary research and education teams ($65 million), nanoscale science and engineering centers ($50 million), exploratory research, and education for high schools and public outreach.

NSF supports fundamental knowledge creation across all disciplinary principles at the nanoscale. A new Center for Hierarchical Nanomanufacturing, to be announced in FY 2006, will establish its operation in FY 2007. This center, together with the existing ones (NNIN; NCN; and Nanoscale Science and Engineering Centers) will establish a research and education platform for nanotechnology at the

[5] http://www.nsf.gov/pubs/2004/nsf0427/nsf0427.pdf

national level, including open and remote access based on merit review, open access, and serve as clearinghouses for information.

Table 1. NSF Directorate Budgets for Nanoscale Science and Engineering
(in millions of dollars)

NSF Directorate	FY 2005 Actual	FY 2006 Current Plan	FY 2007 Request	Change over FY 2006
Biological Sciences	46.78	49.00	52.55	3.55
Computer and Info. Sci.	7.78	12.00	12.87	0.87
Engineering	123.77	127.77	137.02	9.25
Geosciences	7.94	9.00	9.65	0.65
Mathematical and Phys. Sci.	143.27	141.54	156.42	14.88
Social, Behavioral and Econ.	1.57	1.56	1.67	0.11
Office of Intl Sci. and Eng.	0.72	0.00	0.00	0.00
Subtotal, Research & Related	331.83	340.87	370.18	29.31
Education and Human Res.	3.16	2.90	3.00	0.10
Total NNI @ NSF	$334.99	$343.77	$373.18	$29.41

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

- 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;

- 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 2007 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 2007 will contribute to all NNI program component areas. The largest contribution will be to "Fundamental nanoscale phenomena and processes" ($132 million).

The FY 2007 Request includes $59.02 million, an increase of $13.48 million over FY 2006, 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 ($25.65 million). Research will addresses three sources of nanoparticles and nanostructured materials in the environment (in air, water, soil, biosystems, and working environment), as well as the non-clinical biological implications. The safety of manufacturing nanoparticle is investigated in four center/networks: NSEC at Rice University (evolution of manufacturing nanoparticles in the wet environment), NSEC at Northeastern University (occupational safety during nanomanufacturing), NSEC at University of Pennsylvania (interaction between nanomaterials and cells), and National Nanotechnology Infrastructure Network (with two nanoparticle characterization centers at the University of Minnesota and Arizona State University).

- Education-related activities, such as development of materials for schools, curriculum development for nanoscience and engineering, development of new teaching tools, undergraduate programs, technical training, and public outreach ($28.0 million). Two networks for nanotechnology education with national outreach will be supported: The Nanotechnology Center for Learning and

Teaching (NCLT) and the Network for Nanoscale Informal Science Education (NISE).

- Research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, workforce, educational, ethical, and legal implications ($5.37 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. The *Nanotechnology in Society Network* will become fully operational in FY 2007.

Continued funding will be provided for 16 centers of excellence—the Nanoscale Science Engineering Centers (NSECs). The National Nanotechnology Infrastructure Network (with 13 sites for user facilities) and the Network for Computational Nanotechnology (with seven sites) will serve about 12,000 academic and industry users at their facilities. Based on previous history of usage, these 18 centers and networks will provide support for industry partnerships with over 100 companies per year. The Major Research Instrumentation Program and other programs will continue to support the creation of smaller academic nanoscale science and engineering facilities.

DEPARTMENT OF DEFENSE (DOD)

The FY 2007 request is $345 million, which is less than the FY 2006 estimate in the current plan, which includes congressionally directed funds (see Table I-9). This assessment is subject of change because of congressional actions and internal distribution of funds. 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. DOD supports nanoscale science and technology in order to meet the national security mission. The DOD structures its S&T investment into basic research ("6.1"), applied research ("6.2") and advanced technology development ("6.3"); the latter two focus on transitioning science discovery into innovative technology.

New broad agency announcements expected to involve nanotechnology: engineered biomolecular nanodevices/systems, integrated nano-electronics, applications of molecular electronics, negative index materials, synthetic multifunctional materials, and micro cryogenic coolers. Within the Defense Threat Reduction Agency (DTRA) a new nanotechnology program in chem/bio defense has been initiated. Other significant goals are: discovery of new phenomena and processes to enable breakthrough advantages for warfighter and battle systems capabilities; develop robust strategies for synthesis, characterization, and assembly of individual nanostructures; explore applications of nanostructures for revolutionary catalysis, scavengers, taggants, and sensors; elucidate fundamental aspects of phonon and electron transport in individual nanowires and two and three dimensional nanostructures as they relate to the development of high performance thermoelectric, thermionic, and photovoltaic devices for advanced solid state power generation, cooling, and thermal management.

New DARPA programs exploiting nanotechnologies are expected in 2007; 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. Congressionally directed funding for nanotechnology in the DOD budget has increased from an estimated $80 million in 2003, to approximately $100 million in each of the years 2004, 2005, and 2006. 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 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.[6] DOD will provide advanced nanoscience instrumentation via the Defense University Research Instrumentation Program (DURIP).

DEPARTMENT OF ENERGY (DOE)

In FY 2007, the total request is $258 million, including a $51 million increase over FY 2006 current plan (see Table I-9). The FY 2007 request

[6] The DOD nanotechnology budgets and programs are identified at http://nano.gov or http://www.nanosra.nrl.navy.mil.

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, and instrumentation for characterizing materials at the nanoscale. In addition, the FY 2007 request includes a large investment for all five centers—Nanoscale Science Research Centers (NSRC)—of which four will be in full operation in 2007 and one will remain in construction. Support fundamental scientific research into nanoscale phenomena will be via 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. An increased effort will be for research on novel X-ray, electron, and other scattering phenomena to investigate dynamic and ultrafast processes at the nanoscale.

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 Nanoscale Science Research Centers, such as the Center for Integrated Nanotechnologies' "discovery platforms," and other R&D activities on nanomanufacturing processes.

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

The total FY 2007 request by the Health and Human Resources (HHS) department is $173 million and has two main contributions from NIH and NIOSH.

The FY 2007 NIH request is $170 million, about the same as in 2006 current plan.[7]. NIH's priority for nanotechnology research continues to be to create novel diagnostic and therapeutic approaches and devices, and new research capabilities to understand fundamental biomedical mechanisms, leading to improved health of the population and to reduce suffering from disease and disability. Continued ramp-up of nanotechnology R&D funding for programs, including implementing the Nanomedicine Roadmap Initiative, the National Cancer Institute's Nanotechnology Platform Partnerships and Nanotechnology Characterization Laboratory, the National Heart, Lung, and Blood Institute's Programs of Excellence in Nanotechnology, and the Nanotechnology Program Area at the National Institute of Biomedical Imaging and Bioengineering.

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 monitor for adverse effects that may occur during and after treatment. The Nanomedicine Roadmap Initiative and two nanoscience and nanotechnology program announcements (including one for SBIR) are activities coordinated across the institutes and centers of the NIH.

Under the Nanomedicine Roadmap Initiative launched in 2004, NIH funded four Nanomedicine Development Centers in 2005 and will expand the centers program in 2006. The initial goal is to develop and apply new tools with which to extract quantitative information on macromolecular systems in living cells or organisms, generating far more complete predictive models of biology at the molecular and longer length scales than are available today. In the process, engineering principles underlying biology will be developed. In later stages of the program, these discoveries will be used to develop systems for healthcare.

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 National Heart, Lung and Blood Institute (NHLBI) and National Cancer Institute (NCI) nanotechnology programs (with the majority of funding under the PCA on Nanoscale Devices and Systems); (c) a portion of the NCI's

[7] The web site including the NIH roadmap initiatives is http://nihroadmap.nih.gov/

Integrative Cancer Biology program; and (d) a portion of the National Human Genome Research Institute (NHGRI) program to develop novel DNA sequencing technologies (with additional work under the PCA on Nanoscale Devices and Systems), which 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.

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).

At the National Cancer Institute, the NCI's 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 the National Human Genome Research Institute (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's priorities for nanotechnology research continue to be the creation of novel diagnostic and therapeutic approaches and devices, and the development of new research capabilities to understand fundamental biomedical mechanisms. This research will lead to improved health of the population and to reduced suffering from disease and disability.

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. The 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.

The FY 2007 NIOSH request is $3 million, unchanged from the previous year. The Institute will finalize the establishment of a 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. An initial NIOSH document with recommended practices for safe handling of nanomaterials in the workplace has been released.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

The FY 2007, NASA request for nanotechnology programs is approximately $25 million, a decrease of $25 million under the FY 2006 current plan (see Table I-9). The budget is a reflection of 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 (National Cancer Institute) initiative. The OAT 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 MEMS to NEMS, nanoelectromechanical systems).

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.).

The NASA programs have been under review and further revisions are expected as result of the revised mission of the agency.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

The FY 2007 NIST request is $86 million, a $10 million increase from the FY 2006 current plan (see Table I-9). 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 was also 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 unique 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 accelerate their use in new classes of materials, as well as assessing environmental impact. The Center for Nanoscale Science and Technology (CNST) has been established to develop the necessary instrumentation, measurement science, and standards needed for the nanomanufacturing industry and will establish the materials and process characterization needed by industry.

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 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 2007 request is $9 million, a $4 million increase from the FY 2006 current plan (see Table I-9). 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 an area of focus.

EPA will continue to focus the majority of its research in 2007, as in 2006, 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.

US DEPARTMENT OF AGRICULTURE (USDA)

The FY 2007 request is approximately $5 million ($3 million for Cooperative State Research, Education, and Extension Service (CSREES), and $2 million for Forest Service (FS)), about the same as in the FY 2006 Current Plan. USDA conducts its research both extramurally through the partnership between the 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 supports in education and outreach in all the states and territories of the United States through the LGUs.

The USDA nanotechnology program will continue in 2007 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. Another priority will be research on nanoscale properties and behavior of wood and its

constitutive nano-components in order to help capture the value of wood-based lignocellulosic materials and their nanoscale architecture.

DEPARTMENT OF JUSTICE (DOJ)

In FY 2007 the budget request for the DOJ is steady at $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.

Table 2. Key NNI R&D user facilities

Center Name	Institution
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