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National Nanotechnology Investment in the FY 2002 Budget

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INTRODUCTION

The emerging fields of nanoscale science, engineering, and technology—the ability to work at the molecular level, atom by atom, 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 man-made things. The FY 2002 funding request for nanoscale science, engineering and technology (in brief, nanotechnology) research and development (R&D) in eight federal departments and agencies is summarized in Table I-10. The total nanotechnology budget request is approximately $519 million ($485 million as originally reported in the April 9 budget release plus $34 million in associated programs), 23 percent over the $422 million approved by Congress for FY 2001. This investment is known as the National Nanotechnology Initiative (NNI). The National Science and Technology Council (NSTC) Subcommittee on Nanoscale Science, Engineering, and Technology (NSET) will coordinate the federal government's multi-agency nanoscale R&D programs, including planning, budgeting, implementing, developing interagency collaboration, and reviewing the NNI to ensure an efficient investment with broad impact. The R&D strategy is balanced across five kind of activities: fundamental research, Grand Challenges, centers and networks of excellence, research infrastructure, as well as ethical, legal and social implications and workforce programs.[2]

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[2] For more information, on the initiative, see http://nano.gov.

DEPARTMENT OF DEFENSE (DOD)

The FY 2002 NNI request in DOD is $133 million, $23 million over the enacted FY 2001 budget (see Table I-10). This represents a projection from the estimated FY 2001 budget and is subject to change as a result of the Defense Strategy Review now underway in DOD. (Please see Chapter 6 for more information on DOD and the Review.) The request will continue support for the nanoscale science and technology R&D base of $70 million in the Air Force, Army and Navy, and $30 million for the Office of the Secretary of Defense (OSD). In addition, the budget includes basic research funds for the university / DOD laboratory collaborative research programs at the Air Force ($10 million), Army ($10 million), and Navy ($13 million).[3] DOD's priorities are aligned with its Basic Research Plan (OSD's guidance for basic research) and with its Joint Vision 2010, the Chairman of the Joint Chiefs' conceptual template for achieving new levels of warfighting effectiveness. These documents forecast dynamic change in the nature of potential adversaries and emphasize the increasingly critical nature of technological advances

FY 2002 funding will largely be utilized to augment programs in the three NNI R&D Grand Challenges with prime DOD interest—nano-electronics, optoelectronics, and magnetics; nanostructured materials "by design"; and bio-nanosensor devices. The distribution of DOD augmented funds between these three challenges will be determined in collaboration with other NSET agencies: DOE and NASA in nanoelectronics; NSF and DOE in nanomaterials; and NSF, NIH, DOE and NASA in nanobiotechnology, as well as by the quality of proposals received. With its $10 million augmentation, the Army Research Laboratory (ARL) programs will catalyze the recently created ARL Nanoscience and Technology Center (NSTC). The ARL NSTC coordinates active "6.1" (basic research) nanoscience and "6.2" (applied research) nanotechnology research teams in the Sensors and Electron Devices Directorate, the Weapons and Materials Research Directorate, the Computation and Information Science Directorate, and the Army Research Office. With its $10 million, the Air Force Research Laboratory will extend its programs in nanostructured materials, nanofabrication technologies, sensor components, and simulation of nanomaterials. With

[3] For more on the DOD role in NNI, see http://www.nanosra.nrl.navy.mil.

its $13 million, the Navy plans to expand its collaborative University-Naval Research Laboratory program addressing interconnection and interaction between disparate nanostructures in complex systems. Funding for research, equipment, student fellowships have been requested. DOD participation in NNI is coordinated by the Research Director in the Office of the Director of Defense Research and Engineering (DDR&E).

DEPARTMENT OF ENERGY (DOE)

The FY 2002 request of $97 million is an increase of $4 million over FY 2001 for the Basic Energy Sciences (BES) project related to the establishment of user centers for nanoscale science, engineering, and technology research. The funds will allow designated projects for four centers to proceed from conceptual design into definitive design. The FY 2001 base funding of $93 million includes about $36 million for university and national laboratories R&D, and $10.5 million in the Office of Defense Programs. The FY 2001 funding covers approximately $34 million for fundamental research, $29 million for NNI Grand Challenges, $15 million for centers, and $15 million for research infrastructure. An R&D program solicitation of approximately $18 million for university research and $18 million for DOE laboratories is planned.[4]

DEPARTMENT OF JUSTICE (DOJ)

The FY 2002 DOJ budget for nanotechnology R&D is $1.4 million. Major interests are in forensic research, sensors, DNA sequencing, high performance computing, and data base management. The National Institute of Justice (NIJ) is the research agency of the U.S. Department of Justice. NIJ investment of $1 million will continue DNA R&D as well as the demonstration of chip-based or microdevice technologies to analyze DNA in forensic applications. Nanotechnology products 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. NIJ investment of $0.4 million for the Chemical and Biological Defense Program will include developing a

[4] For more on the DOE effort, see http://www.sc.doe.gov/production/bes/BES_FY02budget.pdf.

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. Nanotechnology will be used to address limitations of the enzymatic approach.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The FY 2002 request for NNI in EPA is approximately $5 million. The goal is 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 must also be evaluated. Major nanotechnology-related interests are in aerosols; colloids; clean air and water; and measurement and remediation of nanoparticles in air, water, and soil. The Office of Research and Development (ORD) manages EPA's nanotechnology research, and the National Center for Environmental Research (NCER) manages the external grant solicitation. In addition, NCER has supported a limited number of nanotechnology-based projects through its Small Business Innovation Research (SBIR) Program. In-house research currently includes the National Exposure Research Laboratory and the National Risk Management Research Laboratory, and may expand to other ORD laboratories in the future.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

The FY 2002 request is $46 million, $26 million over FY 2001 (see Table I-10). The FY 2002 breakdown is approximately as follows: $11 million for materials (led by the Langley Laboratory); $15 million for electronics and computing (Ames Laboratory); $10 million for sensors and components (including Jet Propulsion Laboratory (JPL) with $3 million); and $10 million for Basic Nanoscience. NASA's investment in nanoscience and nanotechnology is composed of contributions from several laboratories (mainly Ames, Langley and JPL) and externally supported research. Major themes and new programs in FY 2002 include: (a) manufacturing techniques of single-walled carbon nanotubes for structural reinforcement; electronic, magnetic, lubricating, and optical

devices; and chemical sensors and biosensors; (b) tools to develop autonomous devices that articulate, sense, communicate, and function as a network, extending human presence beyond the normal senses; and (c) robotics using nanoelectronics, biological sensors and artificial neural systems. Due to NASA's relatively modest budget, the Agency will focus primarily on NASA-unique needs, that is: low-power devices and high-strength materials that perform with exceptional autonomy in the hostile space environment. NASA looks to NSF-sponsored work for wide-ranging contributions in fundamental research, and emphasizes work in direct support of the Grand Challenge areas the agency selects for focus, some of them in collaboration with DOD (aerospace structural materials, radiation tolerant devices, and high-resolution imagery), NIH (non-invasive human health monitoring via identification and detection of molecular signatures, and biosensors) and DOE (lab-on-a-chip, and environmental monitoring). A major focus at NASA is to advance and exploit the zone of convergence between nanotechnology, biotechnology and information technology for space exploration. The Agency will spend up to $1 million per year towards an understanding of the societal and ethical implications of nanotechnology, with a focus in the area of monitoring of human health. Opportunities will be sought with university research centers to arrange for student and postdoctoral fellows, including opportunities to work for periods of time at NASA Centers. It is NASA's intent to extend international space mission collaborations into the arena of nanotechnology.

NATIONAL INSTITUTES OF HEALTH (NIH)

The FY 2002 request is approximately $45 million, an increase of $6 million above the approved level for FY 2001. NIH will issue several nanotechnology-related R&D program announcements, that are subsets of the NIH FY 2002 Research Initiatives, of which the most relevant are (a) Genetic Medicine and (b) Clinical Research. The Genetic Medicine Initiative includes large-scale sequencing to assist in interpreting the human sequence, and identifying and characterizing genes that are responsible for variations in diseases. An increased investment in nanotechnology research is planned to develop novel, revolutionary instruments that can be used to collect DNA sequence variation and gene expression data from individual patients, initially to identify genes involved in causing diseases, and later to diagnose exactly which form of the

disease the patient has, to guide therapy that will actually treat that patient's disease. The Initiative in Clinical Research seeks to bridge basic discoveries to tomorrow's new treatments, including nanotechnology advances for development of sensors for disease signatures and diagnosis of diseases. Major themes and new programs in FY 2001 include: biomaterials, clinical diagnostic sensors, genomics sensors, nanoparticles and nanospheres for drug and gene delivery, multidisciplinary training, and studies of social, ethical and legal aspects. The National Institute of Biomedical Imaging and Bioengineering (NIBIB) is in its formative stages at NIH and is expected to be operating by FY 2002. The NIH Bioengineering Consortium (BECON) will coordinate research programs through NIBIB, including nanotechnology research.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

The FY 2002 NNI request in NIST is $17.5 million, a $7.5 million increase over the FY 2001 budget. The funds will be distributed across the NIST Laboratories. NIST will develop the enabling infrastructural measurement and standards for nanomagnetics, nanocharacterization, and new information technologies that will replace semiconductor electronics in the future. Nanomagnetics research will provide measurement and standards for current and near-term applications of nanotechnology in the semiconductor, communications, and health care industries. Nanocharacterization research will produce standards and tools for visualization and characterization at the nanoscale, which are in high demand by a broad base of U.S. industries. Research will be conducted to provide fundamental measurements needed for future generations of information technology hardware that will be needed to replace semiconductor electronics technology in a decade or so. In order to leverage internal efforts, 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. As an agency of the U.S. Department of Commerce, NIST works to help facilitate international trade by working with international standards organizations and national metrology institutes. Key issues in the future for international trade, with

respect to nanotechnology, will be traceability of measurements and "harmonization" of international standards.

NATIONAL SCIENCE FOUNDATION (NSF)

The FY 2002 request for NNI in NSF is approximately $174 million, a $24 million increase over FY 2001. Five of NSF's research directorates participate, as shown in Table 1.

Table 1: National Science Foundation NNI Request for FY 2002
(in millions of dollars budget authority)

Directorate	FY 2001 Estimate	FY 2002 Request
Biological Sciences	2.33	2.33
Computer and Information Sci. and Engineering	2.20	6.20
Engineering	55.27	70.30
Geosciences	6.80	6.80
Mathematical and Physical Sciences	83.08	88.08
Total, Nanoscale Science and Engineering	149.68	173.71

Source: National Science Foundation.

FY 2002 investment will expand a wide range of research and education activities in nanoscale science and technology, in order to develop and strengthen critical fields, to establish the physical science and engineering infrastructure, and to prepare the workforce. Support will be focused on interdisciplinary research and education teams, nanoscale science and engineering centers, exploratory research, and education and training. NSF's five programmatic focus areas are: (a) Fundamental research and education ($107.7 million); (b) Grand Challenges ($7.9 million), with investments in interdisciplinary activities to focus on major long-term challenges; (c) Centers and networks of excellence ($29. million); (d) Research Infrastructure ($19.9 million) for instrumentation and facilities for improved measurements, processing and manipulation at nanoscale, and equipment and software for modeling and simulation; and (e) Societal and educational implications of science and technology advances ($8.8 million) for student assistantships, fellowships and traineeships, curriculum development on nanoscience and engineering and development of new

teaching tools. The impact of nanotechnology on society will be analyzed from legal, ethical, social, and economic perspectives. Collaborative activities are planned with DOD in the area of nanostructured materials and modeling, with DOE in the areas of user facilities and sustainable development, with NASA in nanobiotechnology and nanodevices, with NIH in bioengineering and bionanodevices, with NIST in instrumentation development, and with other agencies. The Nanoscale Science and Engineering (NSE) Group including representatives from all directorates coordinates the NNI activities at NSF.[5]

COLLABORATIVE ACTIVITIES IN FY 2002

The 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 subcommitee will: identify the most promising research directions, identify funding of 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 and complex implications on society such as the effect of nanomaterial manufacturing on the environment, and work to avoid unnecessary duplication of efforts. The subcommittee will also address NNI management issues.

Examples of major collaborative NNI activities crossing the eight agencies with FY 2002 budget requests are shown in Table 2. The State Department is contributing to the international aspects of all topics. DOT, Treausry and USDA also participate in their areas of interest.

[5] For more on NSF efforts, see http://www.nsf.gov/nano.

Table 2. Examples of proposed NNI interagency collaborative activities

Agency	DOD	DOE	DOJ	EPA	NASA	NIH	NIST	NSF
Fundamental research	x	x			x	x		x
Nanostructured materials	x	x		x	x	x	x	x
Molecular electronics	x				x		x	x
Spin electronics	x				x			x
Lab-on-a-chip (nanocomponents)	x	x	x		x	x	x	x
Biosensors, bioinformatics			x		x	x		x
Bioengineering	x	x				x		x
Quantum computing	x	x			x		x	x
Measurements and standards for tools	x	x		x		x	x	x
Nanoscale theory, modeling, simulation	x	x			x			x
Environmental monitoring		x		x	x			x
Nanorobotics		x			x			x
Unmanned missions	x				x			
International collaboration	x	x	x	x	x	x	x	x
Nanofabrication user facilities		x		x	x	x	x	x